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EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

SEPTEMBER, 1921

THE BIOLOGY OF DEATH—VII. NATURAL DEATH, PUBLIC HEALTH, AND THE POPULATION PROBLEM[1]

By Professor RAYMOND PEARL

THE JOHNS HOPKINS UNIVERSITY

1. Summary of Results

IN this series of papers I have attempted to review some of the important biological and statistical contributions which have been made to the knowledge of natural death and the duration of life, and to synthesize these scattered results into a coherent unified whole. In the present paper I shall endeavor to summarize in the briefest way the scattered facts which have been passed in review in the series, and to follow a presentation of the general results to which they lead with some discussion of what we may reasonably regard the future as having in store for us, so far as may be judged from our present knowledge of the trend of events.

What are the general results of our review of the general biology of death? In the first place, one perceives that natural death is a relatively new thing which appeared first in evolution when differentiation of cells for particular functions came into existence. Unicellular animals are and always have been immortal. The cells of higher organisms, set apart for reproduction in the course of differentiation during evolution, are immortal. The only requisite conditions to make their potential immortality actual are physico-chemical in nature and are now fairly well understood, particularly as a result of the investigations of Loeb upon artificial parthenogenesis and related phenomena. The essential and important somatic cells of the body, however much differentiated, are also potentially immortal, but the conditions necessary for the actual realization of the potential immortality are, in the nature of the case, as has been shown by the brilliant researches of Leo Loeb, Harrison and Carrel on tissue culture,

[1] Paper from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 34.

such as can not be realized so long as these cells are actually in and a part of the higher metazoan body. The reason why this is so, and why in consequence death results in the Metazoa, is that in such organisms the specialization of structure and function necessarily makes the several parts of the body mutually dependent for their life upon each other. If one organ or group breaks down, the balance of the whole is upset and death follows. But the individual cells themselves could go on living indefinitely if they were freed, as they are in cultures, of the necessity of depending upon the proper functioning of other cells for their food, oxygen, etc.

So then we see emerging, as our first general result, the fact that natural death is not a necessary or inevitable consequence of life. It is not an attribute of the cell. It is a by-product of progressive evolution—the price we pay for differentiation and specialization of structure and function.

The first result leads logically to the attachment, in any particular organism such as man, of great importance to the quantitative analysis of the manner in which different parts of the body break down and lead to death. Such an analysis, carefully worked through, demonstrates that this breaking down is not a haphazard process, but a highly orderly one resting upon a fundamental biological basis. The progress of the basic tissue elements of the body along the evolutionary pathway is the factor which determines the time when the organ systems in which they are chiefly involved shall break down. Those organ systems that have evolved farthest away from original primitive conditions are the soundest and most resistant, and wear the longest under the strain of functioning. So then, the second large result is that it is the way potentially immortal cells are put together in mutually dependent organ systems that immediately determines the time relations of the life span.

But it was possible to penetrate more deeply into the problem than this by finding that the duration of life is an inherited character of an individual, passed on from parent to offspring, just as is eye color or hair color, though not with the same degree of precision. This has been proved in a variety of ways, first directly for man (Pearson) and for a lower animal, *Drosophila*, (Hyde, Pearl) by measuring the degree of hereditary transmission of duration of life, and indirectly by showing that the death rate was selective (Pearson, Snow, Bell, Ploetz) and had been since nearly the beginning of recorded history, at least. It is heredity which determines the way the organism is put together—the organization of the parts. And it is when parts break down and the organization is upset that death comes. So the third large result is that heredity is the primary and fundamental determiner of the length of the span of life.

Finally, it is possible to say *probably*, though not as yet definitely because the necessary mass of experimental evidence is still lacking, but will I believe be shortly provided, that environmental circumstances play their part in determining the duration of life largely, if not in principle entirely, by influencing the *rate* at which the vital patrimony is spent. If we live rapidly, like Loeb and Northrop's *Drosophila* at the high temperatures, our lives may be gayer, but they will not be so long. The fact appears to be, though reservation of final judgment is necessary till more returns are in, that heredity determines the amount of capital placed in the vital bank upon which we draw to continue life, and which when all used up spells death, while environment, using the term in the broadest sense to include habits of life as well as physical surroundings, determines the rate at which drafts are presented and cashed. The case seems in principle like what obtains in respect of the duration of life of a man-constructed machine. It is self-evident that if of two automobiles of the same make leaving the factory together new at the same time, one is run at the rate of 1,000 miles per year and the other at the rate of 10,000 miles per year, the useful life of the former is bound to be much longer in time than that of the latter, accidents being excluded in both cases. Again, a very high priced car, well-built of the finest materials, may have a shorter duration of life than the shoddiest tin bone-shaker, provided the annual mileage output of the former is many times that of the latter.

The first three of these conclusions I believe to be as firmly grounded as any of the generalizations of science. The last rests at present upon a much less secure footing. Because it does, it offers an extremely promising field for both statistical and experimental research. We need a wide variety of investigations, like those of Loeb and Northrop and of Slonaker, on the experimental side. On the statistical side, well-conceived and careful studies, by the most refined of modern methods, upon occupational mortality seem likely to yield large returns.

2. Public Health Activities

Fortunately, it is possible to get some light on the environmental side from existing statistical data by considering in a broad general way the results of public-health activities, so-called. Any public-health work, of course, deals and can deal in the present state of public sentiment and enlightenment only with environmental matters. Attempts at social control of the germ-plasm—the innate inherited constitutional make-up—of a people, by eugenic *legislation*, have not been conspicuously successful. And there is a good deal of doubt, having regard to all the factors necessarily involved, whether they have always

been even well-conceived. As an animal breeder of some years' experience, I have no doubt whatever that almost any breeder of average intelligence, if given omnipotent control over the activities and destinies of human beings, could in a few generations breed a race of men on the average considerably superior—*by our present standards*—to any race of men now existing in respect of many of his qualities or attributes. But, as a practical person, I am equally sure that nothing of the sort is going to be done by legislative action or any similar delegation of powers. Before any sensible person or society is going to entrust the control of its germ-plasm to science, there will be demanded that science know a great deal more than it now does about the vagaries of germ-plasms and how to control them. Another essential difficulty is one of standards. Suppose it to be granted that our knowledge of genetics was sufficiently ample and profound to make it possible to make a racial germ plasm exactly whatever one pleased; what individual or group of individuals could possibly be trusted to decide what it should be? Doubtless many persons of uplifting tendencies would promptly come forward prepared to undertake such a responsibility. But what of history? If it teaches us anything, it is that social, moral and political standards change, and change radically, with the passing of time. What a group of omnipotent thirteenth century geneticists—all well-meaning, sincere, and, for their time, enlightened individuals—would have thought to be an ideal race of human beings would be very far from what we should so regard to-day. One can not but feel that man's instinctive wariness about experimental interferences with his germ plasm is well-founded.

But because of the altogether more impersonal nature of the case, most men individually and society in general are perfectly willing to let anybody do anything they like in the direction of modifying the environment, or trying to, quite regardless of whether science is able to give any slightest inkling on the basis of ascertained facts as to whether the outcome will be good, bad or indifferent. Hence many kinds of weird activities and propaganda flourish like the proverbial bay tree, and with a singularly unanimous and outspoken manifestation of that unenlightened self-indifference, which is so charming a characteristic of the highest descendants of the anthropoids collectively, we go on paying out large sums of money to the end that they may continue to flourish.

Of all activities looking towards the direct modification of the environment to the benefit of mankind, that group comprised under the terms sanitation, hygiene and public health have by all odds the best case when measured in terms of accomplishment. Man's expectation of life has increased as he has come down through the centuries (cf. Pearson and Macdonell.) A very large part of this improvement

must surely be credited to his improved understanding of how to cope with an always more or less inimical environment and assuage its asperities to his greater comfort and well-being. To fail to give this credit would be manifestly absurd.

But it would be equally absurd to attempt to maintain that all decline in the death-rate which has occurred has been due to the efforts of health officials, whether conscious or unconscious. The open-minded student of the natural history of disease knows perfectly well that a large part of the improvement in the rate of mortality can not possibly have been due to any such efforts. To illustrate the point, I have prepared a series of illustrations dealing with conditions in the Registra-

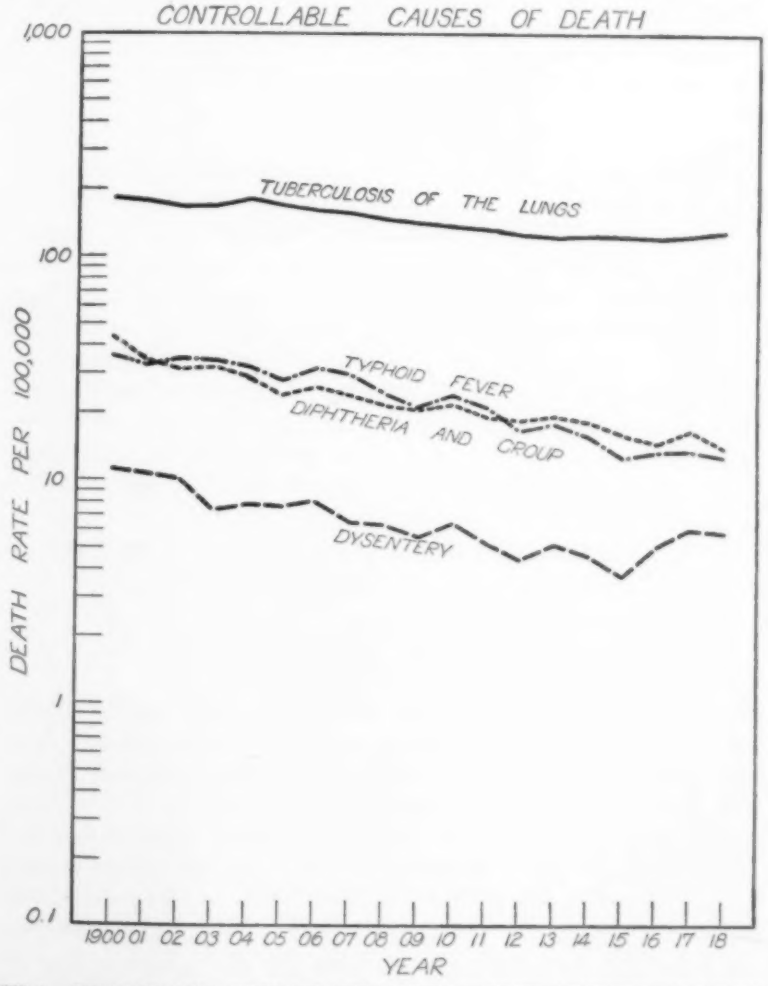

FIG. 1. TREND OF DEATH RATES FOR FOUR CAUSES OF DEATH AGAINST WHICH PUBLIC HEALTH ACTIVITIES HAVE BEEN PARTICULARLY DIRECTED

tion Area of the United States in the immediate past. All these diagrams (Figures 1, 2, and 3) give death rates per 100,000 from various causes of death in the period of 1900-1918, inclusive, both sexes for simplicity being taken together. The lines are all plotted on a logarithmic scale. The result of this method of plotting is that the slope trend of each line is directly comparable with that of any other, no matter what the absolute magnitude of the rates concerned. It is these slopes, measuring improvement in mortality, to which I would especially direct attention.

In Figure 1 are given the trends of the death rates for four diseases against which public health and sanitary activities have been particularly and vigorously directed, with, as we are accustomed to say, most gratifying results. The diseases are:

1. Tuberculosis of the lungs.
2. Typhoid fever.
3. Diphtheria and croup.
4. Dysentery.

We note at once that the death rates from these diseases have all steadily declined in the 19 years under review. But the rate of drop has been slightly unequal. Remembering that the slopes are comparable, wherever the lines may lie, and that an equal slope means a *relatively* equally effective diminution of the mortality of the disease, we note that the death-rate from tuberculosis of the lungs has decreased slightly less than any of the other three. Yet it may fairly be said that so strenuous a warfare, or one engaging in its ranks so many earnest and active workers, has probably never in the history of the world been waged against any disease as that which has been fought in the United States against tuberculosis in the period covered. The rates of decline of the other three diseases are all practically identical.

Figure 2 shows entirely similar trends for four other causes of death—namely:

1. Bronchitis (Acute and Chronic).
2. Paralysis without specified cause.
3. Purulent infection and septicemia.
4. Softening of the brain.

Now it will be granted at once, I think, that public health and sanitation can have had, at the utmost, extremely little if anything to do with the trend of mortality from these four causes of death. For the most part they certainly represent pathological entities far beyond the present reach of the health officer. Yet the outstanding fact is that their rates of mortality have declined and are declining just as did those in the controllable group shown in Figure 1. It is of no moment to say that the four causes of death in the second group are *absolutely* of less importance than some of those in the first group, because what we are here discussing is not relative force of mortality from different causes, but rather the *trend* of mortality from particular causes. The

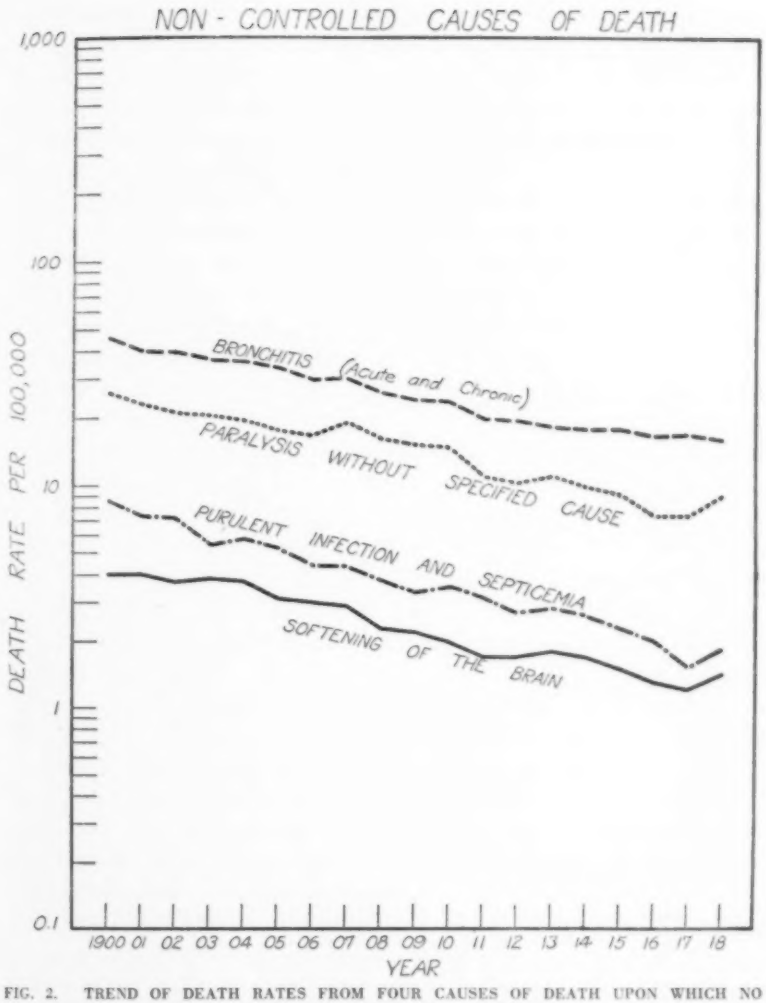

FIG. 2. TREND OF DEATH RATES FROM FOUR CAUSES OF DEATH UPON WHICH NO DIRECT ATTEMPT AT CONTROL HAS BEEN MADE

rate of decline is just as significant, whatever the absolute point from which the curve starts.

It is difficult to carry in the mind an exact impression of the slope of a line, so, in order that a comparison may be made, I have plotted in Figure 3, first, the total rate of mortality from the four controllable causes of death taken together and, second, the total rate of mortality from the four uncontrolled causes taken together. The result is interesting. The two lines were actually nearer together in 1900 than they were in 1918. They have diverged because the mortality from the uncontrolled four has actually decreased faster in the 19 years than has that from the four against which we have been actively fighting.

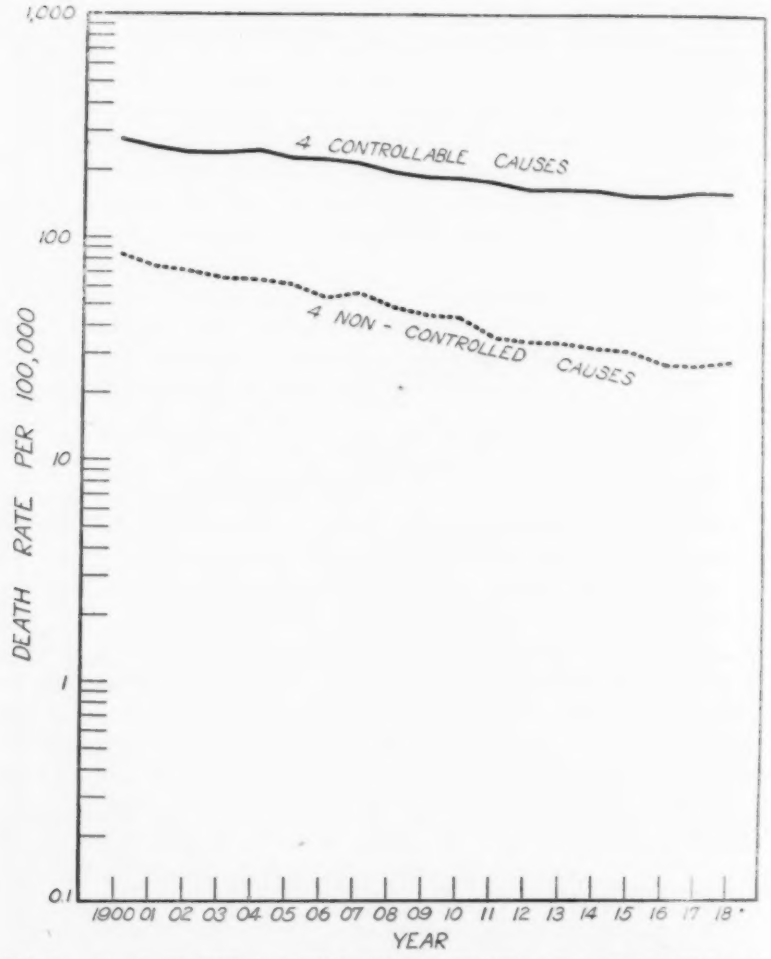

FIG. 3. TREND OF COMBINED DEATH RATE FROM THE FOUR CAUSES SHOWN IN FIGURE 1 AS COMPARED WITH THE FOUR CAUSES SHOWN IN FIGURE 2

The divergence is not great, however. Perhaps we are only justified in saying that the mortality in each of the two groups has notably declined, and at not far from identical rates.

Now the four diseases in this group I chose quite at random from among the causes of death whose rates I knew to be declining, to use as an illustration solely. I could easily pick out eight other causes of death which would illustrate the same point. I do not wish too much stress to be laid upon these examples. If they may serve merely to drive sharply home into the mind that it is only the tyro or the reckless propagandist long ago a stranger to truth who will venture to assert that a declining death-rate in and of itself marks the successful result of human effort, I shall be abundantly satisfied.

There is much in our public health work that is worthy of the highest praise. When based upon a sound foundation of ascertained fact it may, and does, proceed with a step as firm and inexorable as that of Fate itself, to the wiping out of preventable mortality. Some of the work, one regrets to say, has no such foundation, but is built upon the exceedingly shifty sands of ignorance. Having jumped without the slightest real evidence to an unsupported conclusion, the public health propagandist puts into active practice and at great public expense measures which totally lack any scientific validity. I am in great sympathy with the words of the distinguished English pathologist, William Bulloch, who said, in discussing tuberculosis, that he wished "to enter a protest against the wild statements now being made in the lay and medical press, that the whole problem of phthisis was one of infection. Medical history showed that in tuberculosis, as also in the case of other diseases, the most extreme views were taken, not by those who had contributed the actual advancement in knowledge, but by those whose business it was to apply those advancements for the needs of the public. There were a large number of well-ascertained facts which were not entirely explicable on the doctrine that disposition was not an important factor in the genesis of the disease, and that before rigorous measures were applied on a wide scale the actual facts should be ascertained. He did not agree that public health authorities must always 'do something.' This 'doing something' should be put a stop to until there was a reasonable supposition that it was going to achieve its end. He did not wish it to be understood that the tubercle bacillus was not a potent factor. What he did refuse to believe was that it was the only factor. He considered that the disposition, the power of the individual to resist the aggressive inroads of the bacillus, was greater than many people held at the present day."

While this statement of Bulloch's turns upon a controverted issue in the etiology of clinical tuberculosis, namely, as to the relative influence of heredity and environment, the same principle applies to some other phases of public-health work. We shall save a good deal of money and human energy, if we first take the trouble to prove that what we are undertaking to do is in any degree likely to achieve any useful end.

3. The Population Problem

Turning to another phase of the problem, it is apparent that if, as a result of sanitary and hygienic activities and natural evolution, the average duration of human life is greater now than it used to be and is getting greater all the time, then clearly there must be more people on the earth at any time out of a given number born than was formerly the case. It is furthermore plain that if nothing happens to the birth-

rate there must eventually be as many persons living upon the habitable parts of the globe as can possibly be supported with food and the other necessities of life. Malthus, whom every one discusses but few take the trouble to read, pointed out many years ago that the problem of population transcends, in its direct importance to the welfare of human beings and forms of social organization, all other problems. Lately we have had a demonstration on a ghastly gigantic scale of the truth of Malthus' contention. For in last analysis it can not be doubted that the underlying cause of the great war through which we have just passed was the ever-growing pressure of population upon subsistence.

Any system or form of activity which tends by however slight an amount to keep more people alive at a given instant of time than would otherwise remain alive adds to the difficulty of the problem of population. We have just seen that this is precisely what our public-health activities aim to do, and in which they succeed in a not inconsiderable degree. But someone will say at once that while it is true that the death-rate is falling more or less generally, still the birth-rate is falling concomitantly, so we need not worry about the population problem. It is evident that if we regard the population problem in terms of world-area, rather than that of any particular country, its degree of immediacy depends upon the ratio of births to deaths in any given time unit. If we examine, as I have recently done, these death-birth ratios for different countries, we find that they give us little hope of any solution of the problem of population by virtue of a supposed general positive correlation between birth rates and death rates.

The relation of birth-rate and death-rate changes to population changes is a simple one and may be put this way. If, neglecting migration as we are justified in doing in the war period and in considering the world problem, in a given time unit the percentage

$$\frac{100 \text{ Deaths}}{\text{Births}}$$

has a value less than 100, it means that the births exceed the deaths and that the population is increasing within the specified time unit. If, on the other hand, the percentage is greater than 100, it means that the deaths are more frequent than the births and that the population is decreasing, again within the specified time unit. The ratio of deaths to births may be conveniently designated as the vital index of a population.

From the raw data of births and deaths, I have calculated the percentage which the deaths were of the births for (a) the 77 non-invaded departments of France; (b) Prussia; (c) Bavaria; and (d) England and Wales, from 1913 to 1920 by years. The results are shown in Table 1.

TABLE 1

Percentage of Deaths to Births

Year	77 non-invaded departments of France	Prussia	Bavaria	England and Wales
1913	97 per cent	.....	58 per cent.	57 per cent.
1914	110 " "	66 per cent.	74 " "	59 " "
1915	169 " "	101 " "	98 " "	69 " "
1916	193 " "	117 " "	131 " "	65 " "
1917	179 " "	140 " "	127 " "	75 " "
1918	198 " "	132* " "	146 " "	92 " "
1919	154 " "	.....	.....	73 " "
1920	.....	.....	.....	42* " "

* First three-fourths of year only.

The points to be especially noted in Table 1 are:

1. In all the countries here dealt with the death-birth ratio in general rose throughout the war period. This means that the proportion of deaths to births increased so long as the war continued.

2. But in England it never rose to the 100 per cent. mark. In other words, in spite of all the dreadful effects of war, England's net population went on increasing throughout the war.

3. Immediately after the war was over, the death-birth ratio began to drop rapidly in all countries. In England in 1919 it had dropped back from the high figure of 92 per cent. in 1918 to 73 per cent. In France it dropped from the high figure of 198 in 1918 to 154 in 1919, a lower figure than France had shown since 1914. In all the countries the same change is occurring at a rapid pace.

Perhaps the most striking possible illustration of this is the history of the death-birth ratio of the city of Vienna, shown in Figure 4, with data from the United States and England and Wales for comparison. Probably no single large city in the world was so hard hit by the war as Vienna. Yet observe what has happened to its death-birth ratio. Note how sharp is the decline in 1919 after the peak in 1918. In other words, we see how promptly the growth of population tends to regulate itself back towards the normal after even so disturbing an upset as a great war.

In the United States, the death-birth ratio was not affected at all by the war, though it was markedly so by the influenza epidemic. The facts are shown in Figure 4 for the only years for which data are available. The area covered is the United States birth registration area. We see that with the very low death-birth ratio of 56 in 1915, there was no significant change till the influenza year 1918, when the ratio rose to 73 per cent. But in 1919, it promptly dropped back to the normal value of 57.98, almost identical with the 1917 figure of 57.34.

In England and Wales, the provisional figure indicates that 1920

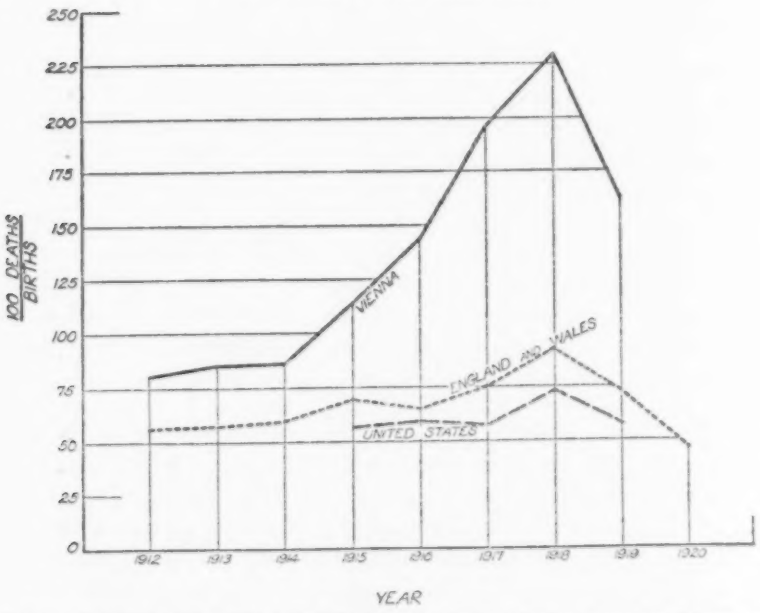

FIG. 4. SHOWING THE CHANGE IN PERCENTAGE WHICH DEATHS WERE OF BIRTHS IN EACH OF THE YEARS 1912 TO 1919 FOR VIENNA (———); 1915 TO 1919 FOR THE UNITED STATES (— — —); AND 1912 TO 1920 FOR ENGLAND AND WALES (.....)

will show a lower value for the vital index than that country has had for many years.

So we see that neither the most destructive war the modern world has ever known nor the most destructive epidemic since the Middle Ages serves more than to cause a momentary hesitation in the steady onward march of population growth.

The first thing obviously needed in any scientific approach to the problem of population is a proper mathematical determination and expression of the law of population growth. It has been seen that the most devastating calamities make but a momentary flicker in the steady progress of the curve. Furthermore, population growth is plainly a biological matter. It depends upon, in last analysis, only the basic biological phenomena of fertility and mortality. To the problem of an adequate mathematical expression of the normal growth of populations, my colleague, Dr. Lowell J. Reed, and I have addressed ourselves for some time past. The known data upon which we have to operate are the population counts given by successive censuses. Various attempts have been made in the past to get a mathematical representation of these in order to predict successfully future populations, and to get estimates of the population in inter-censal years. The most noteworthy attempt of this sort is Pritchett's fitting of a parabola of the third order to the United States population from 1790 to 1880 in-

clusive. This gave a fairly good result over the period, but was obviously purely empirical, expressed no real biological law of change, and in fact failed badly in prediction after 1890.

We have approached the problem from an *a priori* basis, set up a hypothesis as to the biological factors involved, and tested the resulting equation against the facts for a variety of countries. The hypothesis was built up around the following considerations:

1. In any given land area of fixed limits, as by political or natural boundaries, there must necessarily be an upper limit to the number of persons that can be supported on the area. To take an extreme case, it is obvious that not so many as 25,000 persons could possibly stand upon an acre of ground, let alone live on it. So similarly there must be for any area an upper limiting number of persons who can possibly live upon it. In mathematical terms this means that the population curve must have an upper limiting asymptote.

2. At some time in the more or less remote past the population of human beings upon any given land area must have been nearly or quite zero. So the curve must have somewhere a lower limiting asymptote.

3. Between these two levels we assume that the *rate* of growth of the population, that is, the increase in numbers in any given time unit, is proportional to two things, namely:

a. The absolute amount of growth (or size of population) already attained;

b. The amount of as yet unutilized, or reserve, means or sources of subsistence still available in the area to support further population.

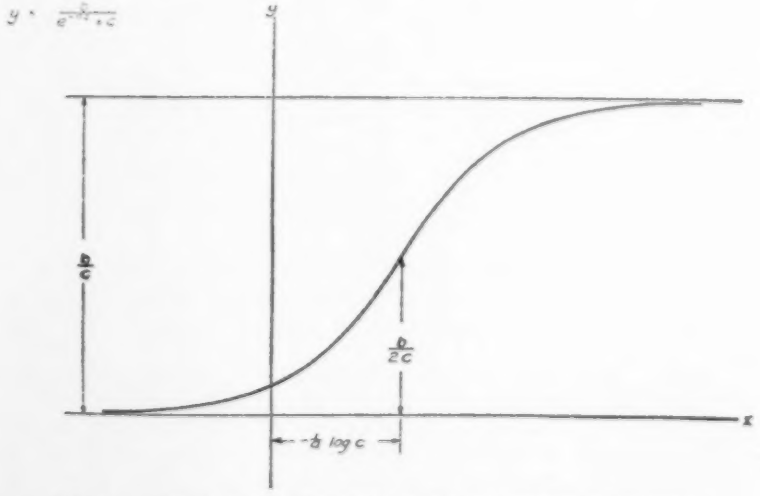

FIG. 5. SHOWING THE THEORETICAL CURVE OF POPULATION GROWTH

These hypotheses lead directly to a curve of the form shown in Figure 5, in which the position of the asymptotes and of the point of inflection, when the population is growing at the most rapid rate, are shown in terms of the constants. It is seen that the whole history of a population as pictured by this curve is something like this: In the early years following the settlement of a country the population growth is slow. Presently it begins to grow faster. After it passes the point where half the available resources of subsistence have been drawn upon and utilized, the rate of growth becomes slower, until finally the maximum population which the area will support is reached.

This theory [2] of population growth makes it possible to predict what the maximum population in a given area will be, and when it will be attained. Furthermore, one can tell exactly when the population is growing at the maximum rate. To test the theory, we have only to fit this theoretical curve to the known facts of population for any country by appropriate mathematical methods. If the hypothesis fits well all the known facts for a variety of countries in different stages of population growth, it may well be regarded as a first approximation to a substantially correct hypothesis and expressive of the biological law according to which population grows. In making this test the statistician has somewhat the same kind of problem that confronts the astronomer calculating the complete orbit of a comet. The astronomer never has more than a relatively few observations of the position of the comet. He has, from Newtonian principles, a general mathematical expression of the laws of motion of heavenly bodies. He must then construct his whole curve from the data given by the few observations. So similarly the statistician has but a relatively few population observations because census taking has been practiced along present lines only a little more than a century. According to the stage in historical development of the country dealt with he may have given an early, a late, or a middle short piece of the population "orbit" or history. From this he must construct on the basis of his general theory of "population orbits" the whole history, past and future, of the population in question.

To demonstrate how successful the population curve shown in Figure 5 is in doing this, three diagrams are presented, each illustrating the growth of the population in a different country. The heavy

[2] The mathematical hypothesis here dealt with is essentially the same as that of Verhulst put forth in 1844. As Pearl and Reed pointed out in this first paper on the subject it is a special case of a much more general law. A comprehensive general treatment of the problem we are publishing shortly in another place. The generalization in no way alters the conclusions drawn here from a few illustrative examples.

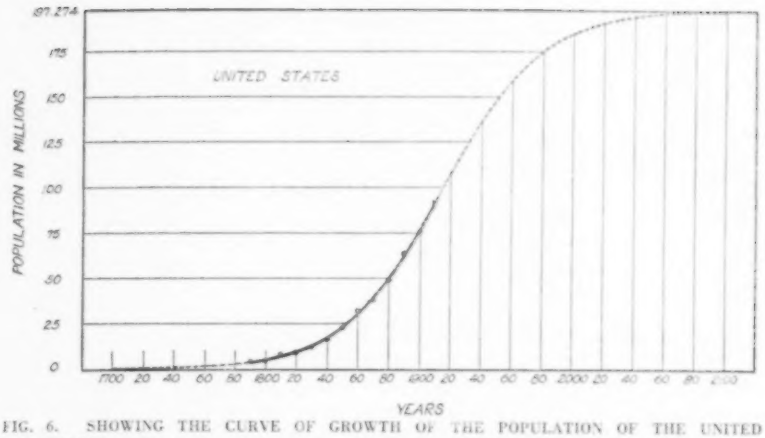

FIG. 6. SHOWING THE CURVE OF GROWTH OF THE POPULATION OF THE UNITED STATES. For further explanation of this and the two following diagrams, see text.

solid portion of each curve shows the region for which census data exist. The lighter broken part of the curve shows the portions outside this observed range. The circles show the actual, known observations. The first curve deals with the population of the United States. Here the observations come from the first part of the curve, when the population was leaving the lower asymptote. First should be noted the extraordinary accuracy with which the mathematical theory describes the known facts. It would be extremely difficult by any process to draw a curve through the observed circles and come nearer to hitting them all than this one does.

Before considering the detailed consequences of this United States curve in relation to the whole population history of the country, let us first examine some curves for other countries where the observed data fell in quite different portions of the "population orbit." Figure 7

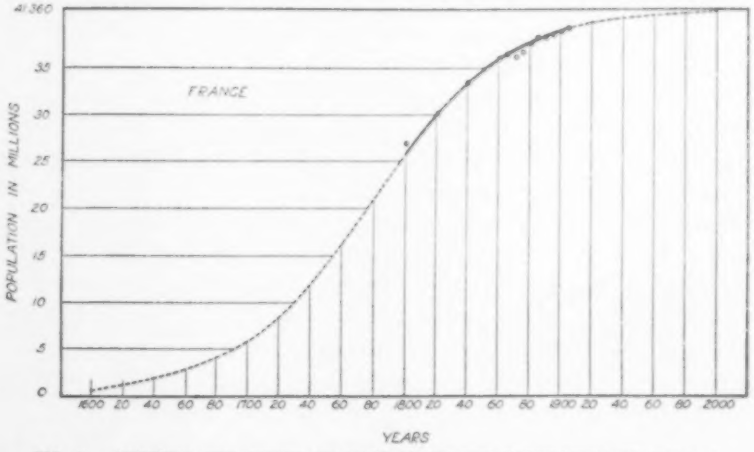

FIG. 7. SHOWING THE CURVE OF GROWTH OF THE POPULATION OF FRANCE

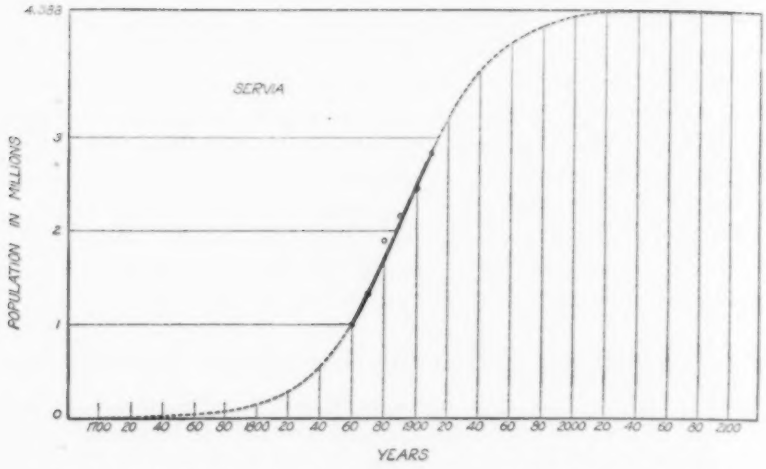

FIG. 8. SHOWING THE CURVE OF GROWTH OF THE POPULATION OF SERBIA

gives the curve for France. Since before the time when definite census records began France has been a rather densely populated country. All the data with which we had to work belong therefore towards the final end of the whole population history curve. The known population data for France and for the United States stand at opposite ends of the whole historical curve. One is an old country whose population is nearing the upper limit; the other a new country whose population started from near the lower asymptote only about a century and a half ago. But it is seen from the diagram that the general theory of population growth fits very perfectly the known facts regarding France's population in the 120 years for which records exist. While there are some irregularities in the observation, due principally to the effects of the Franco-Prussian war, it is plain that on the whole it would be practically impossible to get a better fitting line through the observational circles than the present one.

We have seen that the general theory of population describes with equal accuracy the rate of growth in a young country with rapidly increasing population and an old country where the population is approaching close to the absolute saturation point. Let us now see how it works for a country in an intermediate position in respect of population. Figure 8 shows the population history of Serbia. Here it will be noted at once that the heavy line, which denotes the region of known census data, lies about in the middle of the whole curve. Again the fit of theory to observation is extraordinarily close. No better fit by a general law involving no more than 3 constants could possibly be hoped for.

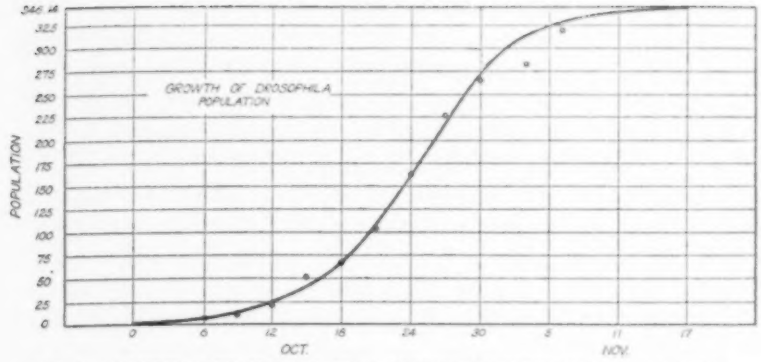

FIG. 9. SHOWING THE GROWTH OF A *DROSOPHILA* POPULATION KEPT UNDER CONTROLLED EXPERIMENTAL CONDITIONS

I think that these three examples, which could be multiplied to include practically every country for which accurate population data exist, furnish a cogent demonstration of the essential soundness and accuracy of this theory of population growth. Indeed, the facts warrant, I believe, our regarding this as a first approximation to the true natural law of population growth. We now have the proper mathematical foundation on which to build sociological discussions of the problem of population.

As a further demonstration of the soundness of this theory of population growth, let attention be directed for a moment to an example of its experimental verification. To a fruit fly (*Drosophila*) in a half pint milk bottle such as is used in experimental work on these organisms, the interior of the bottle represents a definitely limited universe. How does the fly population grow in such a universe? We start a bottle with a male and a female fly, and a small sample, say 10, of their offspring of different ages (larvae and pupae). The results are shown in Figure 9. The circles give the observed population growth, obtained by census counts at 3-day intervals. There can be no doubt that this population has grown in accordance with our law. The two final observations lie below the curve because of the difficulty experienced in this particular experiment of keeping the food supply in good condition after so long a period from the start.

Let us return to the further discussion of the population problem of the United States in the light of our curve.

The first question which interests one is this: When did or will the population curve of this country pass the point of inflection and exhibit a progressively diminishing instead of increasing rate of growth? It is easily determined that this point occurred about April 1, 1914, on the assumption that our present numerical values reliably represent the law of population growth in this country. In other

words, so far as we may rely upon present numerical values, the United States has already passed its period of most rapid population growth, unless there comes into play some factor not now known and which has never operated during the past history of the country to make the rate of growth more rapid. The latter contingency appears improbable. The 1920 census confirms the result, indicated by the curve, that the period of most rapid population growth was passed somewhere in the last decade. The population at the point of inflection works out to have been 98,637,000, which was in fact about the population of the country in 1914.

The upper asymptote given by our equation has the value 197,274,000 roughly. This means that the maximum population which continental United States, as now areally limited, will have will be roughly twice the present population. This state of affairs will be reached in about the year 2,100, a little less than two centuries hence. Perhaps it may be thought that the magnitude of this number is not sufficiently imposing. It is so easy, and most writers on population have been so prone, to extrapolate population by geometric series or by a parabola or some such purely empirical curve and arrive at stupendous figures, that calm consideration of real probabilities is most difficult to obtain. While we regard the numerical results as only a rough first approximation, it remains a fact that if anyone will soberly think of every city, every village, every town in this country having its present population multiplied by 2, and will further think of twice as many persons on the land in agricultural pursuits, he will be bound, we think, to conclude that the country would be fairly densely populated. It would have about 66 persons per square mile of land area.

It will at once be pointed out that many European countries have a much greater density of population than 66 persons to the square mile, as, for example, Belgium with 673, the Netherlands with 499, etc. But it must not be forgotten that these countries are far from self-supporting in respect of physical means of subsistence. They are economically self-supporting, which is a very different thing, because by their industrial development at home and in their colonies they produce money enough to buy physical means of subsistence from less densely populated portions of the world. We can, of course, do the same thing, provided that by the time our population gets so dense as to make it necessary there still remain portions of the globe where food, clothing material and fuel are produced in excess of the needs of their home populations.

Now 197,000,000 people will require on the basis of our present food habits about 260,000,000 million calories per annum. The United States, during the seven years 1911-1918, produced as an annual aver-

age, in the form of human food, *both primary and secondary* (*i. e.*, broadly vegetable and animal), only 137,163,606 million calories per year. So that, unless our food habits radically change, and a man is able to do with less than 3,000 to 3,500 calories per day, or unless our agricultural production *radically* increases, which it appears not likely to do for a variety of reasons which can not be here gone into, it will be necessary when even our modest figure for the asymptotic population is reached to import nearly or quite one-half of the calories necessary for that population. It seems improbable that the population will go on increasing at any very rapid rate after such a condition is reached. East, in what appears to be the most able and penetrating discussion of population of this generation, has shown that the United States has already entered upon the era of diminishing returns in agriculture in this country. Is it at all reasonable to suppose that by the time this country has closely approached the asymptote here indicated, with all the competition for means of subsistence which the already densely populated countries of Europe will then be putting up, there can be found any portion of the globe producing food in excess of its own needs to an extent to make it possible for us to find the calories we shall need to import?

Altogether, we believe it will be the part of wisdom for any one disposed to criticize our asymptotic value of a hundred and ninety-seven and a quarter millions because it is thought too small, to look further into all the relevant facts.

The relation of this already pressing problem of population to the problem of the duration of life is obvious enough. For every point that the death rate is lowered (or, what is the same thing, the average duration of life increased) the problem of population is made more immediate and more difficult unless there is a corresponding decrease in the birth-rate. Is it to be wondered at that most thoughtful students of the problem of population are ardent advocates of birth-control? Or is it remarkable that Major Leonard Darwin, a son of Charles Darwin and president of the Eugenics Education Society in England, should say in a carefully considered memorandum to the new British Ministry of Health: "In the interests of posterity it is most desirable that parents should now limit the size of their families by any means held by them to be right (provided such means are not injurious to health, nor, like abortion, an offence against public morals) to such an extent that the children could be brought up as efficient citizens and without deterioration in the standards of their civilization; and that parents should not limit the size of the family for any other reasons except on account of definite hereditary defects, or to secure an adequate interval between births."

It seems clear that the problem of population can not be com-

pletely or finally solved by limitation of the birth-rate, however much this may help to a solution. There are two ways which have been thought of and practiced, by which a nation may attempt to solve *its* problem of population after it has become very pressing and after the effects of internal industrial development and its creation of wealth have been exhausted. These are, respectively, the methods of France and Germany. By consciously controlled methods France endeavored, and on the whole succeeded, in keeping her birth-rate at just such delicate balance with the death-rate as to make the population nearly stationary. Then any industrial developments simply operated to raise the standard of living of those fortunate enough to be born. France's condition, social, economic and political, in 1914 represented, I think, the results of about the maximum efficiency of what may be called the birth-control method of meeting the problem of population.

Germany deliberately chose the other plan of meeting the problem of population. In fewest words, the scheme was, when your own population pressed too hard upon subsistence, and you had fully liquidated the industrial development asset, to go out and conquer some one, preferably a people operating under the birth-control population plan, and forcibly take his land for your people. To facilitate this operation a high birth-rate is made a matter of sustained propaganda and in every other possible way encouraged. An abundance of cannon fodder is essential to the success of the scheme.

Now the morals of the two plans are not at issue here. Both are regarded, by many people, on different grounds to be sure, as highly immoral. Here we are concerned only with actualities. There can be no doubt that in general and in the long run the bandit plan is bound to win over the birth-control plan if the issue is joined between the two and *only* the two, if its resolution is purely military in character, and if there is no international police force of a magnitude and courage adequate to cope with bandit and otherwise criminal nations. As between two nations, allowed free rein to "fight it out" by themselves without help or hindrance, the decisive element is a mathematically demonstrable one. A stationary population where birth-rate and death-rate are made to balance is necessarily a population with a relative excess of persons in the higher age groups, not of much use as fighters, and a relative deficiency of persons in the lower age groups where the best fighters are. On the contrary, a people with a high birth-rate has a population with an excess of persons in the younger age groups.

So long as there are on the earth aggressively minded peoples who from choice deliberately maintain a high birth-rate, no people can afford to put the birth control solution of the population problem into too extensive operation until such time as the common-sense of man-

kind decides that peace is in fact a more desirable state of society than war and implements this decision to practical realization through some international equivalent of a police force, which will restrain by force, and plenty of it, the activities of disturbers of the peace. "Disturbance of the peace" is not tolerated in our domestic affairs. It is no more a virtue in international relations. The only effective method which society has yet devised to secure that our home peace shall not be seriously disturbed is that of an adequate police force. There appears no insuperable difficulty in applying the same principle internationally. And any competent economist can easily show that its cost as compared with war would be extremely small. Because something of the sort is not done, one seems bound, however reluctantly, to conclude that nations as nations *prefer* wars and the opportunities for wars to a state of enduring peace. What a long way the average human intellect has still to proceed on its evolutionary pathway!

IMPENDING PROBLEMS OF EUGENICS [1]

By Professor IRVING FISHER

YALE UNIVERSITY

I feel a double sense of my unworthiness of the honor which you have bestowed upon me by electing me president of this association. On the one hand, I feel that eugenics is incomparably the most important concern of the human race and, on the other, I am painfully aware of the fact that I can bring to you no original contribution. All that I can hope to do is to point out from my viewpoint as a student of economics, and to some extent of hygiene, the opportunities which would seem to mark out some of the paths which eugenists should explore more fully.

My main thought is that there is now a golden opportunity for eugenists to "gear in," so to speak, with the great world of events. It was the dream of Galton that eugenics should not forever remain academic but that, being the vital concern of us all, it should become a sort of religion. Hitherto eugenics has been largely studied "microscopically," that is, by special technical laboratory investigations. The next step is to study it more "telescopically," that is by observations of the general facts of human history.

I do not mean, of course, that eugenists should drop their study of the inheritance of finger prints or of the inheritance of musical capacity, eye defects, skeleton abnormalities and twinning. The work of Pearson in London and of Davenport here and of their co-workers and colleagues everywhere must go on uninterruptedly. But in addition to all these, steps should be taken to organize a study of the eugenics or dysgenics of such historical events as war, immigration, colonization, prohibition, hygiene, birth control, feminism, capitalism, industrialism, democracy, socialism, bolshevism, population growth, urbanization and diminishing returns in agriculture.

It is interesting to observe in passing that these historical occurrences are due in large part to the inventions and discoveries of civilization, including especially those of rapid transportation, military science, hygienic knowledge and devices for birth control. These inventions are generally regarded as landmarks of progress. They have, thus far, undoubtedly caused progress in *economic* well-being and permitted an ever increasing *number of people* to subsist in a given area.

[1] Address of the president of the Eugenics Research Association, Cold Spring Harbor, June 24.

Mechanical inventions, particularly those which abridge distance, have given us more and more room for expansion and we have mistaken this progressive conquest of nature for a progressive improvement in ourselves. A few years ago the then president of the American Economic Association cited the increase of population as the best obtainable criterion of "progress."

But the eugenist is interested in the quality of human beings rather than their quantity, and one of the great problems to be seriously considered, is whether our boasted "progress" is not an illusion and whether after all the human race, in spite of its rapid multiplication and its increase in per capita wealth, may not be deteriorating. The discovery that this is the case would doubtless surprise and shock the country just as did the discovery that one man out of every three in our army draft was unfit. The common opinion is undoubtedly that we have made great progress and are making great progress now. The same opinion was held, so historians tell us, just before the downfall of Rome and of other civilizations which have failed.

We know that affluence often ruins men and women, and history has at least produced a strong suspicion that it was the cause, or *a* cause, of ruin of many civilizations now dead. As Goldsmith says:

> Ill fares the land to hastening ills a prey,
> Where wealth accumulates, and men decay.

The economist has shown that wealth accumulates. The eugenist may show that men decay. Dr. Pearce Bailey states that in the army examinations mental defectives amounted to two thirds of one per cent. and he concluded that a greater proportion existed in the general population.

The statistics of the feeble-minded, insane, criminals, epileptics, inebriates, diseased, blind, deaf, deformed and dependent classes are not reassuring, even though we keep up our courage by noting that the increasing institutionalization of these classes gives the appearance of an increase which in actual fact may be non-existent because institutionalization makes it possible to collect these statistics.

In Massachusettes thirty-five per cent. of the state income goes in support of state institutions and Mr. Laughlin, the secretary of this association, who compiled the government report on defectives, delinquents and dependents, estimates that seventy-five per cent. of the inmates have bad heredity. The cost of maintaining these institutions in the United States in 1915 was eighty-one millions of dollars. This takes no account of the town and county care, while all the official costs fail to take into account the cost to families and associates, the keeping back of school children by the backward children, the cost from fires of pyro-maniacs, the cost from thievery of kleptomaniacs, the cost from crime, vice, etc., of paranoiacs, maniacs and paretics and the loss of

services of able men and women drained away from other use to take care of the defectives, delinquents and dependents.

I believe that any one who has worked in these statistics with the sincere desire to get the truth has an uneasy feeling that degeneracy may be really increasing and increasing fast. Several competent students in eugenics and related fields have already reached strong convictions on the subject.

As I write, I find Professor William McDougall's new book, "Is America Safe for Democracy?" in which he says: "As I watch the American nation speeding gaily, with invincible optimism, down the road to destruction, I seem to be contemplating the greatest tragedy in the history of mankind." Research should make our conclusions on this subject beyond question. A great load of degeneracy is certainly upon us, whether it be true or not that it is increasing in weight. It is incumbent upon us to reduce it. The first step is to measure it.

There are many startling evidences of racial decay. One is that the war has damaged the potential fatherhood of the race by destroying over seven million young men, medically selected for fighting but thereby prevented from breeding. In quantity the loss of seven million men by war is not great. If numbers were really our criterion of progress we could take comfort in the fact that the world as a whole to-day has undoubtedly more inhabitants than before the war. The gap made by the war has been more than filled. This was mostly outside of Europe. In a few years Europe itself will catch up.

But small as is the number of lives lost as a fraction of population, their loss may nevertheless be the loss of most of the good male germ plasm of the nations concerned, particularly in Europe. In the United States, of course, the war has been less injurious.

Herbert Spencer, David Starr Jordan, Vernon Kellogg and others have urged with convincing force this reason for believing that war, in general, is dysgenic.

Professor Roswell H. Johnson maintains that war may sometimes be eugenic, that it is always partly so, although he has no hesitation in concluding that the recent world war has left a big net dysgenic balance.

We all agree, I think, that the destruction of seven million picked young men in their prime is not only an irretrievable loss for this generation but for all succeeding generations—increasingly rather than otherwise. A little reflection will show the argument. In the first place, to apply the argument backward, let us consider that our parents were probably above the average of their generation. This is evidenced by the very fact that they were parents. None of them died in infancy: for if they had they could not have been parents. They all had enough vitality to have gone through childhood and enough vitality and at-

tractiveness to become married and to have children. To put their supposed superiority in figures, let us, to fix our ideas, assume that they constituted the upper *fifty* per cent. of their generation. The other half of the people in their generation have left no living descendants.

Our grandparents were, in turn, presumably a still more select class of the generation in which they lived, for they not only had the vitality to become parents but, in every single case they possessed the vitality to have had at least some children strong enough themselves to become parents. These grandparents, therefore, unlike our parents were not simply the upper fifty per cent. of their generation but, let us say, the upper *forty* per cent. Some of the remaining sixty per cent. had children but their progeny ceased there and did not last to the second generation. Likewise our great grandparents were still more select, forming, let us say, the upper *thirty* per cent. of their generation, the other seventy per cent. having no descendants surviving through three generations to the present day. And so the further back we go the more select must have been our ancestors, until when we reach one thousand years back it may be that (if there were only a Eugenics Record Office to tell us) we should find, say, but ten per cent. of that generation who had left any descendants in ours. Had that ten per cent. been medically selected out and commissioned to shoot each other to death none of us to-day would be here but instead there would be the descendants of inferior stock. And that would seem to be what must happen a thousand years hence. Europe will be inhabited by the descendants of second-rate men of to-day simply because they can not be descendants of those who now sleep in Flanders Fields.

But such pessimistic conclusions are apt to be rejected as too terrible to be believed. Hope and optimism spring eternal in the human breast. Jeremiahs and Cassandras are always unpopular. If the eugenic argument against war is fallacious it should be disproved, while if it is correct it should be fortified by further research.

During the next decade there should be a wealth of statistical material on this subject, which should enable us not only to demonstrate further the truth but to bring the truth, whatever it be, home to the men and, more particularly, to the women of all lands.

It may be, of course, that the bad results of the war in other countries will be neutralized by some counterbalancing good results. It is one of the fundamental laws of human behavior to react so to an evil as to convert it into a good. We did not have safety at sea until the *Titanic* disaster had opened our eyes to the need. New York City did not have a good health department until afflicted by an epidemic. We have still reason to hope that the world war and the prospect of another, tenfold more horrible, as portrayed in Will Irwin's book "The Next War," may supply the needed stimulus to organize the

nations into an "association," or *a* league, or *the* league, to abolish war or at least to minimize, localize and control it.

And I have the further hope that the results of the eugenic research in this field, may in the not distant future, give so great an impetus to eugenics as a great social movement as ultimately to neutralize the dysgenic effect of the great war.

If nothing of the sort happens and there should be lacking the brains and energy to accomplish at least some of these things, then surely the dark ages lie ahead of us. The Nordic race will, as Madison Grant says, vanish or lose its dominance if, in fact, the whole human race does not sink so low as to become the prey, as H. G. Wells imagines, of some less degenerate animal!

With this thought in view we should perhaps shudder as well as laugh at the reflections of Clarence Day in his entertaining phantasy "This Simian World," where he observes what a different place this world would be if its masters, instead of being the descendants of anthropoid apes, were the descendants of lions or elephants, or other types of the animal kingdom!

But the obvious direct effect of war in destroying so much of the best germ plasm from which our race would otherwise be largely bred is by no means the only possible dysgenic effect of the war. Hrdlicka thinks that the roar of artillery and the other excitements of battle may make such an impression on the nervous system of soldiers as to affect injuriously their children.

Similarly there should be considered the possible effects on future generations of the undernourishment and general undercare of the children and other noncombatants who will be the parents of the next generation.

Dr. Lorenz, of Vienna, was recently quoted as saying that the average child of Vienna is about four inches below the normal height and sixteen and a half pounds below the normal weight, that thousands are suffering from rickets and not infrequently from broken bones which have given way because of their unhealthy condition.

We are apt to shut our eyes to these possibilities of race damage from the unsanitary environment and unhygienic mode of life brought about in Europe by the war because of the widely accepted dictum that acquired characters are not inherited. On this assumption we are in danger of jumping to the conclusion that the stunted, rickety or generally decrepit individuals now constituting a large part, probably a majority, of the European population will have children just as large and healthy as these particular parents could have had under ordinary circumstances. We are severely told that rickets and broken bones are not inherited.

Conklin says: "How could defective nutrition, which leads to the

production of rickets, affect the germ cells, which contain no bones, so as to produce rickets in subsequent generations, although well nourished?"

But granted all this as "gospel truth," its complacent application to the existing European conditions would be altogether unjustified and misleading.

Conklin himself, on the very next page after that from which I have quoted, expresses an important qualification. He says "that unusual conditions of food, temperature, moisture, etc., may affect the germ cells so as to produce general and indefinite variations in offspring is probable, but this is a very different thing from the inheritance of acquired characters."

For our present purposes, however, the difference is small and the similarity great. If the depleted vitality of Europe is to show in future generations it is just as much depletion whether general or specific, whether the rickets of this generation will be followed in the next by rickets or by tuberculosis or neuro-pathic conditions or feeble-mindedness or any other manifestation of damage done. From a practical point of view the question is whether damage to the present generation will still be damage in succeeding generations, and not the technical question of whether the specific form of that later damage will be the same as of the present damage. Biologists are in danger of deluding themselves by clinging to form rather than substance in this instance however technically correct is the insistence that acquired characters are not inherited.

In this insistence they often give the impression, if in fact they do not receive it themselves, that the sins and misfortunes of this generation are not visited on the next. Observations and experiments on the mutations of the primrose, of yeast and of insects indicate that environment often does leave permanent marks on the species. Gy in France has found that tobacco not only damaged the animals on which he experimented but their offspring as well. Van der Wolk found that maple trees injured by bacterial infection (rot) gave rise to leaves of a changed color and to flowers which, unlike the original, were monosexual; also that these changes were transmitted. The bacterial infection thus originated a new species!

One great field, therefore, for eugenic research is the study of the extent to which future generations are damaged because of damage received by their parents of the present generation, in other words the extent to which hygienic or unhygienic conditions for the individual are eugenic or dysgenic for his offspring—in short, the extent to which hygiene is eugenic.

If it be true, as I have little doubt, that the recent unhygienic conditions of war are sure to crystallize into permanent dysgenic condi-

tions of peace, it is, by the same token, also true that in general and quite irrespective of the war eugenics must take account of hygiene.

Now if what is poison to the individual is in general poison to the race, if what helps or hurts the individual in his own life leaves, to some extent, a beneficial or harmful impress on posterity, then the importance of eugenics is greatly extended and it becomes a task of eugenic research to study the extent to which the indiscretions and bad environment, on the one hand, or the good habits and good environment, on the other, affect our descendants. And it becomes a mission of the eugenics movement to discover and set itself against race poisons. These may include not only alcohol, habit-forming drugs and infections but, if Gy is right, tobacco and, if Kellogg is right, even tea and coffee. We have no right, in the present state of our knowledge, to assume that these are harmless to the race, if they are harmful to the individual.

I would emphasize this partly because, so far as I have any right at all to speak as a eugenist, it is on account of studies in the neighboring field of hygiene.

Civilization has thrown the daily life of the individual out of balance, so that not one person in a hundred lives what might be called a biologic life. He is insufficiently exposed to the air, he eats too fast and often too much. In America he eats far too much protein and far too little bulk. His food is far too soft. It is usually lacking in vitamines. His evacuations are too infrequent, his posture is usually abnormal and unhealthful. His activities are too one-sided. His mind is too excited, worried and hurried. Worst of all, he is the unconscious victim of many physical poisons and infections. The examinations of the Life Extension Institute show some physical imperfections in practically every person examined. And the average man is blissfully unconscious of the damage he thus does himself, cumulatively, day after day and year after year. Yet this damage keeps on like a creeping fire under the leaves in the woods.

Hygiene and eugenics should go hand in hand. They are really both hygiene—one individual hygiene and the other race hygiene—and both eugenics—one indirectly through safeguarding the quality of the germ plasm and the other directly through breeding.

I do not mean to assert that hygiene, as practiced, is necessarily eugenic. It may well be true that *misapplied* hygiene—hygiene to help the less fit—is distinctly dysgenic. I remember being astonished at the attitude of a university president, who became very enthusiastic over the triumph of hygiene saying, "I know of a girl who had many disabilities. She had a surgical operation to remedy one difficulty and a course of hygiene to remedy others, so that finally she was so repaired and improved as to be converted into quite a respectable human being

and now she is married." Schools for tubercular children give them better air and care than normal school children receive. Institutional care of defectives often surpasses that in the home.

Eugenic research can help the eugenic cause by showing the folly of such differential care of the biologically unfit, especially when such differential care is not accompanied by safeguarding against the marriage of the unfit. Undoubtedly the rule of eugenics should be "to those that have shall be given" and this maxim will have added eugenic worth the more it can be shown that biologic gifts belong not only to the present generation, but to all that come after.

The picture of this world and especially of Europe suggested to our minds by what has thus far been said is that population is increasing in quantity but declining in quality.

At present the world contains seventeen hundred million people and, according to Professor East, its population is increasing by about fifteen millions per annum. It is fast filling up the empty spaces of the globe. The rapid filling up of North America during the last century will surely be followed by the filling up of South America and Africa in the next century.

In a few generations as Thompson and East emphasize, the expansion in numbers must itself approach an end. Within the life time of many living there will, in all probability, come a realization such as at present scarcely exists of the profound truths set forth by Malthus at the beginning of the nineteenth century. We must not be deceived by the exceptional conditions under which we have been living in the last two or three centuries. The opening up of America gave a new outlet for population and reduced and postponed the operation of Malthus' checks to population. Mechanical inventions, which increased physical productivity, had the same effect. But after the lands now empty are full and those now waste are reclaimed no increase of the food-producing area of the globe is conceivable. Nor is it likely that inventions which have made two blades of wheat grow where one grew before can go on at a geometrical progression and so keep pace with the biologically possible growth of population. And unless this be possible population must necessarily in a few generations come practically to a halt, either by the relentless check of an increased death rate or by the more preventive check of a decreased birth rate.

What will be the eugenic significance of this future limiting of population? This is one of the great questions for eugenic research. The answer will doubtless depend largely on which of the two checks will be put on population, whether it is to be the check from an increased death rate operating through lack of subsistence or the check from a decreased birth rate operating by volition of parents.

The former check shown by Malthus led Darwin to conceive his

theory of natural selection, which in turn led Galton to suggest eugenics.

In so far as the future check on population is to be of this kind, even though an increased death rate involve much misery, the presumption is that, on the whole, it will be eugenic rather than dysgenic in its effects. Those should survive who are best fitted to earn a livelihood. But this is, as the critics of Malthus complained, a dismal outlook.

The operation of the other check is not so obvious. To-day we have, in a way and to a degree of which Malthus probably never dreamed, the exercise of this prudential check under the title of neo-Malthusianism or birth-control.

Until recently this subject was not discussed in the open, partly because the movement had not gained sufficient momentum, partly because of the conventional reticence on all matters of sex and partly because of the continual existence (in this country alone among the nations of the earth) of laws passed at the instigation, chiefly, of Anthony Comstock, forbidding the dissemination of information on birth-control.

But the subject is one especially deserving eugenic research; for, of all human inventions, those relating to birth-control probably have the most direct bearing on the birth rate and its selective possibilities.

It is startling to think that the sex impulse which hitherto has been the unerring reliance of nature to insure reproduction can no longer be relied upon. Some insects sacrifice their lives to reproduction. Nature relies on their blind instinct to reproduce regardless of any consequences to themselves. If we could suppose such an insect suddenly to be given an option in the matter so that it could satisfy its sex impulse without the consequences of offspring or of immediate death to itself, its instinct of self-preservation would presumably refuse to make the ancient sacrifice and the species would perish from off the earth.

In the case of the human species nature demands no such extreme sacrifice of the mother; if this were the case birth control would almost surely mean the ultimate extinction of the human race. But the human mother has nevertheless had to sacrifice personal comfort and both parents have had to sacrifice some economic well-being and some social ambitions to meet the obligations of parenthood. Hitherto the only effective ways to avoid this and still satisfy the sex instinct have been infanticide and abortion. Birth-control offers another way, easier, less objectionable and therefore destined to be far more widely practiced among civilized peoples.

This is largely a development of "feminism" in the interests of women. It opens up amazing possibilities of race extinction or, on the other hand, of race betterment.

If the birth-control exercised by individual parents could itself be controlled by a eugenic committee it could undoubtedly become the surest and most supremely important means of improving the human race. We could breed out the unfit and breed in the fit. We could in a few generations and, to some extent even in the life time of us of to-day conquer degeneracy, dependency and delinquency, and develop a race far surpassing not only our own but the ancient Greeks.

Thus birth-control is like an automobile. It can convey us rapidly in any direction. As now practiced which way is it carrying us? Where will birth-control really take us? This is a matter for eugenic research to settle. There are three possibilities: (1) it may cause depopulation and ultimately bring about the extinction of the human race; (2) it may reduce the reproduction of the prudent and intelligent and the economically and socially ambitious, leaving the future race to be bred out of the imprudent, unintelligent and happy-go-lucky people, thus resulting in race degeneration; or (3) it may cut off the strain of the silly and selfish, the weak and inefficient who will dispense with children for the very good reason that they lack the physical stamina or the economic ability to support a large family.

The advocates of birth-control maintain, with much show of reason, that it diminishes poverty, increases efficiency, prevents damage to the mother's health, and improves the health and education of the children.

What does history tell us so far? The best opinion seems to be that in Holland birth-control has reduced infant mortality by making better intervals between successive children and by increasing their size and vigor as well as the per capita wealth of the country. In countries where birth-control has been exercised only a short time the reduction in the total number of births has been accompanied by an almost equal reduction in the total number of deaths. There is a distinct correlation between the death rate and the birth rate so that a moderate amount of birth-control need not reduce much, if at all, the rate of increase of population. In Russia, Roumania, Bulgaria and Serbia, presumably without birth-control and where the birth rates are forty or fifty per thousand, there is an increase of population between fifteen and twenty per thousand, and in Australia and New Zealand, with birth control and where the birth rates are from twenty-five to thirty per thousand, there is substantially the same rate of increase. When birth-control in these last named countries has been in use longer and more generally the same effects as in France may perhaps be expected. In France population was actually declining before the war, a situation realized in no other country, except in the time of the World War, when it was temporarily true of England, Serbia and some other countries.

It is worth noting here that if feminism is to have a depopulating effect the first element it will extinguish is the feminist element itself.

So far as it elevates woman, feminism is to be commended. But friends of womankind should heed well the warning of some other movements which contained the seeds of their own destruction. "Shakerism" killed itself because it shunned marriage. Feminism may kill itself if it shuns children. A bragging feminist recently referred to the old child-bearing women as a type which has disappeared below the historical horizon. If it has, then the type which will not bear children will surely disappear in its turn just because it will have no children in its own image.

The world's experience with birth-control thus far does seem to show that the average family which practices it does not practice it in the required moderation. Dublin has shown that, under present conditions, it takes an average of about four children in the family for the upkeep of population. An average of three means decrease of population and an average of five means increase of population.

But aside from the danger of depopulation as shown in France is the question of the kind of selective birth rate which birth-control will bring about. Will this be a good or a bad selection? As birth-control leaves births to human choice instead of to instinct, many jump to the conclusion that this is necessarily a step forward. But whether it is or not depends on how this human choice will actually operate.

Professor McDougall has given reason to believe that the present occupational stratification of society corresponds roughly to the stratification of intelligence; that the four classes, (1) professional men and business executives, (2) other business men, (3) skilled workmen and (4) unskilled workmen represent on the whole four classes of human beings graded as to innate mental ability. The college graduate means the professional man and business executive.

Cattell finds that the average Harvard graduate is the father of three-fourths of a son and the average Vassar graduate the mother of one-half of a daughter and that the average family of American men of science is only 2.22 as compared with an average of 4.66 for the country. Popenoe and Johnson give similar results summarizing many statistical studies of Yale, Harvard, and other educational institutions.

At present, then, our educational system seems to be destroying the very material on which it works! Colleges seem to be engines for the mental suicide of the human race! Are the colleges of to-day sterilizing our scholars as did the monasteries and nunneries of the middle ages? Such race suicide of scientific and educated men and of the well-to-do classes means that their places will speedily be taken by the unintelligent, uneducated and inefficient.

Up to the present time, so far as I can see, birth-control has done harm to the race, exactly in the same way as has the war.

But it is plain that the extension of birth-control to all classes will tend to rectify this condition. At present it is practiced only in the

upper one or two of the four strata which McDougall distinguishes in his statistics. Its extension is rapidly going on, thanks to the propaganda of Sanger, Drysdale and others and will inevitably include all classes eventually. It is therefore too early to condemn utterly birth-control. It may still prove to be a great instrument for eugenic improvement.

It will probably require long years of research to determine what the ultimate effect will be. The hypothesis which now seems to be probable is that there will be three stages.

The first effect of birth-control seems, as has been said, distinctly bad because it is first practised by the intelligent class and is, for that class, as Mr. Roosevelt said, "race suicide."

The second effect will be that where birth-control is practised among all classes, as has almost been the case in France, an actual decline in population will occur which will seem alarming.

The third effect may then follow. It is a rapid repopulation from the small minority of the strongest, most efficient, and the most child-loving and altruistic persons of the population. We all know people who, though fully aware of the possibilities of birth-control, nevertheless do not practise it or do not practise it to excess, but rear large old-fashioned families because they love children, can afford to have them, and have no physical or economic difficulties in bearing and raising them. These vigorous champions of humanity will doubtless possess not only physical strength but the intelligence necessary to earn a sufficient livelihood to justify their choice of having large families.

Whenever civilizations have decayed, and many probably have done so from race suicide, their places have been taken by strong and fecund invaders. In the case of birth-control the invasion need not come from outside. It may come from inside the decadent nation itself. It is said that, in this way, the Breton portion of the French population is replacing the other portions. Multiplying by geometrical progression, a tenth part of our population can in a few generations of large families fill up all the gaps made by birth-control and make a stronger race than we ever have had. Should this rosy prospect actually work out in the twenty-first or twenty-second century, birth-control would go down in human history, like the flood in the Bible, as a means first of wiping out the old world and then replacing it by a new, from the best seeds of the old.

At any rate, while there are undoubtedly grave possibilities of evil facing us in birth-control, we must not be misled by averages. The *average* Harvard graduate may not reproduce his kind, but among thousands of college graduates there will almost certainly be found a *few* who do and by geometrical progression the few can become the majority.

An apparent objection to this forecast is that the most reckless will practice birth-control the least and so will have the greatest number of children. But this objection may possibly be answered by the fact that such people will soon become public charges, as paupers for instance, and that we may then stop their reproduction by enforcing celibacy, segregating the sexes.

But the truth is that we can not yet tell what will ultimately happen as the net result of birth-control, whether race degeneracy, depopulation, or race improvement or, as I have suggested, all three in succession.

One of the claims of enthusiastic advocates of birth-control is that it will help save us from further war because it will save us from that pressure of population which results in imperialistic ambitions. Huxley and others are quoted to support the view that pressure of population and the need of an outlet for surplus population lie behind emigration, colonization, conquest and war. It is inferred that the real remedy for the yellow peril or the "rising tide of color" must consist in the extension of birth-control to the Orient. How much truth there is in this view is a matter for eugenic research to determine. The same argument for extending birth-control to other nations applies as for extending it to other races within our own.

At present the white race is still increasing faster than the other races but it is easy to see that birth-control will soon put an end to this unless birth-control is extended from the white race to the colored. Birth-control, war and immigration are certainly associated problems.

Economically, immigration of cheap labor is beneficial (initially at least) to capital and injurious (initially at least) to native labor. The conflict between these two interests, of capital and of labor, constitutes most of what is ordinarily included in the immigration problem.

The core of the problem of immigration is, however, one of race and eugenics, despite the fact that in the eighteen volumes of the report of the Immigration Commission scarcely any attention is given to this aspect of the immigration problem. If we could leave out of account the question of race and eugenics I should, as an economist, be inclined to the view that unrestricted immigration, although injurious to some classes, is economically advantageous to a country as a whole, and still more to the world as a whole. But such a view would ignore the supremely important factors.

The character of the present immigration will make a great difference in the character of our future inhabitants.

Between 1788 and 1840 England sent many of its undesirables to Botany Bay, near Sydney, Australia, and to-day the excessively large slums of Sydney are, according to the findings of Dr. Davenport, to a large extent the progeny of those undesirables. At present the United

States inherits, both socially and biologically, probably as much from the eighty thousand original immigrants, who, Benjamin Franklin said, had come to this country up to 1741, as from all the other immigrants since that time. Our problem is to make the most of this inheritance. We can not do so if that racial stock is overwhelmed by the inferior stock which "assisted" immigration has recently brought.

If we allow ourselves to be a dumping ground for relieving Europe of its burden of defectives, delinquents and dependents, while such action might be said to be humane for the present generation, it would be quite contrary to the interests of humanity for the future. Not only should we be giving these undesirable citizens far greater opportunity to multiply than they had at home, but we would be taking away the checks on the multiplication of those left at home. It would be a step backward, a step towards populating the earth with defectives, delinquents and dependents. That the foreign born multiply faster than the native stock has been shown by the Immigration Commission and by East, Dublin, Baker and others. There is great danger, therefore, not only to this country, but to the whole world, of injuring the germ plasm of the human race by the indiscriminate immigration of recent times. The best service we can render, not only to ourselves, but in the end to those very nations which would feign empty their almshouses, asylums and prisons on us, is to prevent their doing so. In the words of Professor Ross in "The Old World in the New":

> I am not of those who consider humanity and forget the nation, who pity the living but not the unborn. To me, those who are to come after us stretch forth beseeching hands as well as do the masses on the other side of the globe. Nor do I regard America as something to be spent quickly and cheerfully for the benefit of pent-up millions in the backward lands. What if we become crowded without their ceasing to be so? I regard it (America) as a nation whose future may be of unspeakable value to the rest of mankind, provided that the easier conditions of life here be made permanent by high standards of living, institutions, and ideals which finally may be appropriated by all men. We could have helped the Chinese a little by letting their surplus millions swarm in upon us a generation ago; but we have helped them infinitely more by protecting our standards and having something worth their copying when the time came.

What has been said applies to immigration even from countries of our own race.

The problem of Oriental immigration has a somewhat special character. It involves race prejudice and impossibility of assimilation, socially and racially. The arguments usually brought forward in this connection are largely partisan and inconsistent. The Japanese immigrant in California is hated as belonging to an inferior race, on the one hand, and, on the other because his industry, frugality and intelligence are such that the native laborer can not compete with him. In other words he is hated both because he is inferior and because he is superior.

Of him I would say, as of immigrants generally, that from a narrow, shortsighted economic point of view, his immigration should be encouraged, but if we should let down the bars for Oriental immigration, under modern conditions of rapid transportation, the country might be inundated with Chinese, Japanese and Hindoos. We should then lose even that modest degree of political solidarity which we now possess. There would probably be a demoralization and disintegration of our general social structure and, what most concerns us, we should add to our present southern and black race problem a western and yellow race problem; race wars, lynchings and massacres, such as we have just been witnessing would ensue. Ultimately, if not speedily, actual war with a United Asia would undoubtedly be brought about. What Japan has done in one generation, China can do in the next. And when China is fully equipped with battleships, machine guns, aeroplanes and poisonous gases, she and Japan could possibly conquer the whole white world.

We have often laughed at the yellow "peril" especially when it was the nightmare of the Kaiser. But later he showed us what peril may be in even one comparatively small nation. To-day the yellow color peril is the subject of a seriously alarming book by Lothrop Stoddard, "The Rising Tide of Color." It is in the thoughts of many far-seeing people on the Pacific coast. Under unrestricted immigration, within a century a majority of this country might become Oriental, especially if we commit race suicide. It would require only a few years for millions to enter and by geometrical progression it requires only a few generations for millions to become scores or hundreds of millions.

What has been said is from the point of view of our own white race and American nationality. Theoretically and academically it may be that true eugenics for the human race as a whole may favor some other race than ours, and that, say, yellow domination rather than white domination, may, in some distant future, be the ideal domination. But we can not be expected, especially in the absence of any proof that we are an inferior race, to act on that assumption and quietly lie down and let some other race run over us.

Again, it is possible that the ideal for remotely future ages may be a human race which is a mixture of all existing human races. That is also a subject for eugenic research. The solution, for instance, of the Jewish problem, if such exists, may be their racial assimilation. But if such a mixture is ever effected, especially a mixture of widely different races, it must come slowly. We can not ignore race prejudice, and any sudden mixture is sure to produce an unstable compound, which will blow up in race war and social demoralization. Professor East believes that the black and white mixture in Africa will be one of

the greatest of race problems three generations hence. The obvious safeguard at present is restriction of immigration of a drastic kind. This should be done tactfully and reasonably. As Stoddard points out, if the white world does not wish to be dominated by the world of color it ought to cease its own attempts at dominating the latter.

Of the great problems which I mentioned at the outset, I have sketched briefly the problems of war, hygiene, birth-control and immigration in their relations to eugenics.

The results of a cursory bird's eye view seem to indicate that much of what we call progress is an illusion and that really we are slipping backwards while we seem to be moving forwards. Human ambitions under the opportunities afforded by civilization seem to sacrifice the race to the individual. We congregate in great cities and pile up great wealth but are conquered by our very luxury. We seek imperial power and not only damage but destroy our germ plasm in war. We seek social status and education but limit motherhood. Like moths attracted by a candle, we fly toward the glamour of wealth and power and destroy ourselves in the act.

In concluding this telescopic review of big eugenic problems, I may be permitted to point out the directions in which it seems to me we may hope for remedies.

If it be granted that war is dysgenic, then a League or Association of Nations which will prevent or minimize war is an important eugenic device.

If it be true that birth-control among the intelligent is due, to a certain extent, to the fact that children are an economic handicap, Professor McDougall's suggestion of putting an economic premium on large families among the fit ought not to be overlooked. A millionaire like Carnegie, instead of pensioning professors or rewarding heroes, might subsidize children among a specific group of biologically fit to be determined by a committee of award. Ultimately when public opinion is ripe, the government might subsidize the children of school teachers also instead of, as is at present sometimes the practice, discharging women school teachers if they marry.

Coeducation in colleges ought not to go unmentioned as promising somewhat to increase the marriage rate among college graduates.

Segregation of the sexes in public institutions is a eugenic device of undoubted value. It does no violence to our humanitarian ideas to take care of the present crop of undesirables on condition that they shall not act as seeds for future crops.

If it be granted that, from our standpoint at least, indiscriminate immigration is dysgenic, a discriminating exclusion must be eugenic. Laughlin's proposal of having aliens examined in their home town for mental and other defects is full of promise. The proposal of registra-

tion of immigrants and then deporting and purging the country of the most undesirable among them as soon as these undesirables turn up later at feeble-minded and other institutions is likewise full of promise.

Doubtless much can be added to this meager program as a consequence of eugenic research and some things may be subtracted from it.

But, in order to lead to anything practical and effective eugenic research must be followed by, and in fact accompanied by, some far-reaching publicity. I mean that there must be a diffusion of the knowledge gained and, what is far more important from the standpoint of securing action, a diffusion of a sense of the pre-eminent importance of eugenics. Finding ourselves in the shadow of the Great War, in a world damaged by that war and by the other causes of degeneracy which have been mentioned, we can not stand silently by and see the general public enjoying a fool's Paradise. In the bliss of ignorance they mistake economic production and expansion for genuine progress and, with the best of intentions are, we fear, paving the road to hell.

There are millions of people in the world to-day whose enthusiastic support for eugenics could probably be obtained at the price of a little publicity. We now have a golden opportunity that should not be missed.

One means of enlightening the public is through increasing interest in hygiene, especially individual hygiene. Charity begins at home and, psychologically, the only route to race hygiene is through individual hygiene.

The teaching of both hygiene and eugenics in schools and colleges merely enough to show the elements of both, including the Mendelian principles of heredity and the responsibility of each person to the race, will appeal alike to self interest and to that idealism which is always present in young people whose lives lie ahead of them. Just as the Catholic church proselytes by getting children at the formative age, just as prohibition got its grounding in the public schools, so hygiene and eugenics can become the life-long possession of the next generation if inserted in the school books of the present generation.

In our public schools should also be included educational and mental measurements. They are rapidly coming into use in our colleges and universities throughout the nation. They emphasize individual differences and will serve to correct the view that "men are created equal" in the biological sense while leaving them equal in opportunity before the law.

We may hope that the proposed national Department of Public Welfare will spread knowledge in regard to scientific "humaniculture" as knowledge of scientific agriculture has been spread through the Department of Agriculture.

Another vehicle or starting point which should not be forgotten is

the coming International Congress of Eugenics in the fall. Extraordinary pains should be taken to see that the newspaper, magazine and moving picture publicity in regard to that congress may be adequate and effective. This congress should be followed up by an organized movement for general publicity on eugenics. This may, or may not, be the proper function of the Eugenics Research Association. If it is not, a new association should be started as a go-between to connect scientific research with the public.

Needless to say, in any propaganda care must be exercised to prevent the hasty endorsement of unproved methods and theories. But there is ample basis already for a movement the initial purpose of which will not be so much a detailed specific program as a general spread of the idea that eugenics is the hope of the world. Details can wait. Where there is a will there is a way and without a will there is certainly no way at all. While eugenic science is painfully finding the way there is ample work for a propaganda organization to secure the will.

I believe in Galton's idea that eugenics must be a religion. It will prove a wonderful touchstone by which to distinguish between what is racially and radically right and what is racially and radically wrong. It will bring home to parents the thought that much, if not all, of their conduct may be fraught with future significance for their children and children's children. It will throw its searchlight into every nook and cranny in the life of the individual and of society.

Therefore it will help mould all human institutions. Especially will it help mould that fundamental institution, human marriage. While marriage is a most intensely individual and private matter, it has been regarded, from time immemorial, as of vital concern to society. Around this great institution of human marriage have always clustered many sorts of folkways. In civilized times the law has made legitimate marriage a binding contract and religion has given it its divine blessing. It now remains for science which in so many other ways is remodeling the whole modern world, to affix its seal of approval.

And just as law and religion discriminate and refuse their seal of approval to alliances which are found to be improper from their respective viewpoints, so must science discriminate. Dysgenic marriages must be discountenanced just as bigamous or incestuous marriages are discountenanced.

In thus withholding or giving a coveted approval eugenic science will elevate marriage in its way as greatly as have law and religion in theirs. It will shed the light of reason on the primeval instinct of reproduction. It will exalt what is already a "legal contract" and "holy matrimony" into a dedication of all we are to what we want posterity to be.

A FEW QUESTIONABLE POINTS IN THE HISTORY OF MATHEMATICS

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MOST of the professional mathematical historians have been basement builders and many of our general histories of mathematics remind one of the church buildings which consist of a basement roofed over while funds for completing the structure are being awaited. In some cases, such as Cantor's noted *Vorlesungen über Geschichte der Mathematik*, the basement is not even roofed over.

In fact, the work of Cantor might remind one in a mild way of the following statement in the Scriptures: "This man began to build and was not able to finish." If it is true that about *fifteen* volumes would be required in order to cover the developments of the nineteenth century as completely as Cantor covered the period up to the beginning of this century, as is suggested in the preface to Volume 1 of Dickson's "History of the Theory of Numbers," 1919, it results that Cantor did not complete one-fifth of the job of writing a general history of mathematics up to the end of his scientific activity.

It seems questionable whether a basement history, even when the basement is roofed by slight attention to the developments of the nineteenth and the twentieth centuries, is the most suitable history to place in the hands of the young student. Present day activities in mathematics have received entirely too little attention even on the part of the students who specialize in this subject.

A considerable number of questions in the history of mathematics have been answered differently by different writers and hence this subject offers unusual opportunities for the exercise of judgment and for argumentation. To some this may appear to be an attractive feature since disputation has long been recognized as a useful educational exercise and elementary mathematics presents comparatively few questions to which different answers have been given by good recent writers. Hence the student of this subject is inclined to confine his attention too closely to questions which can be answered definitely.

It is not the object of the present paper to give a definite answer to some of the questions which have been in dispute for a long time but rather to direct attention to a few more questions which seem to be

open to dispute, in the hope that the interest in these questions may thereby be increased and the interest in the history of our subject may thus be fostered. In the main the present writer will present here arguments exhibiting a point of view which is not in accord with the one presented in the second edition of Cajori's "History of Mathematics," 1919, and our references to pages relate to this work.

On page 142 it is stated that "the foremost French mathematician before Vieta was Peter Ramus (1515-1572), who perished in the massacre of St. Bartholomew." It can not be assumed that the fact that Ramus perished during the massacre of St. Bartholomew constitutes a a claim to mathematical fame since thousands of others were then slain, but one consults the index of Cajori's history in vain for other reasons for calling Ramus the foremost French mathematician before Vieta.

It is interesting to note that in the history of many a country there is a record of some mathematician who is very much better known than any of his predecessors in the same country. As instances we may cite Newton in England, Leibniz in Germany, Napier in Scotland, Abel in Norway, etc. In some cases very little is known about any of the predecessors of such a man in the country in question. For instance, G. A. Gibson stated that before Napier (1550-1617) Scotland made not a single contribution to mathematical science [1]. In case more is known about the predecessors of such a man it is a question of some interest to inquire into the relative merits of their contributions.

Hence one is naturally interested in knowing something about the work of the French predecessors of Vieta who is doubtless much better known than any of these predecessors. Among these there are, in addition to Ramus, such favorably known men as N. Oresme and N. Chuquet. The reader who recalls the many references to the works of the last two mathematicians (e. g., on page 14 of tome 3, volume 3, of the "Encyclopédie des Sciences Mathématiques" G. Eneström notes that a work by Oresme serves as a graphic preamble to the introduction of analytic geometry) will naturally wonder why Ramus is placed ahead of them in both editions of Cajori's "History of Mathematics."

It is true that Ramus is better known in general than Oresme or Chuquet, but Ramus is known principally on account of his attacks on the accepted views of his day and not on account of his contributions towards the advancement of mathematics. In mathematics he also exhibited his quarrelsome disposition but he failed even to understand the more subtle points involved in some of the mathematical methods which he attacked. He emphasized the importance of teaching the practical methods of calculation employed by the merchants of the street and his mathematics was of the business college type rather than of the university type.

[1] "Napier Tercentenary Celebration Handbook," 1914, p. 2.

His contention that the method of giving a collection of definitions first, as is done in Euclid's "Elements," is unnatural since a forest was not created by growing the roots of the trees first may have had considerable influence on later textbooks on elementary mathematics. It is, however, a question whether a quarreling and quarrelsome dialectician, such as Ramus was, should be placed ahead of Oresme and Chuquet as a mathematician even if his activities had a wholesome influence on mathematical instruction and may have been largely responsible for the early and radical departure from Euclid's "Elements" on the part of French textbooks on geometry.

As the names of Oresme and Chuquet are prominent in the history of exponents in elementary mathematics, the former having used fractional exponents and the latter the exponent zero, their work naturally calls in question the following statement found on page 149: "It is one of the greatest curiosities in the history of science that Napier constructed logarithms before exponents were used." The notion of exponents and not the formal use of them in the modern way is related to the development of logarithms, and this notion was much older even than the work of Oresme, who lived more than two centuries before Napier.

In view of the great mathematical influence of the Ecole Normale of Paris it may be of interest to refer to the statement found in various places to the effect that its first students were young pupils. For instance, on page 256, it is stated that "at the establishment of the *Ecole Normale* in 1795 in Paris, he (Lagrange) was induced to accept a professorship. Scarcely had he time to elucidate the foundations of arithmetic and algebra to young pupils, when the school was closed."

While the term "young pupils" is not very definite, yet few people would be likely to associate it with students whose ages varied from 21 to 66. In fact, according to "Le Centenaire de l'Ecole Normale," 1895, page 125, nearly half of these "young pupils" were from 30 to 60 years old, and among them was Bougainville, a celebrated navigator, who was 66 years old. The law prescribed that none of these students should be less than 21 years old but it did not fix an upper limit to their ages as the best prepared available students were desired.

In view of the great influence which this ephemeral experiment had on the teaching of mathematics and other sciences in the secondary schools of France and the fact that the professors of mathematics (Lagrange, Laplace and Monge) were eminent mathematicians, it is of interest to know that these early students, who were paid to come to Paris from various parts of France, were not "young pupils" in the sense in which this term is commonly understood, but were, in the main, mature men who could derive much profit from a profound presentation of the elements of various educational subjects. Some of

Lagrange's lectures prepared for these students were translated by T. J. McCormack and published in 1901 under the title "Lectures on Elementary Mathematics by Joseph Louis Lagrange," The Open Court Publishing Company.

It may be noted here that the official journal of this normal school during the first brief period of its existence was entitled *Séances des Ecoles Normales*, and not *Journal des Ecoles Normales* as is stated in various places including the *Encyklopädie der Mathematischen Wissenschaften*, volume 3, page 519, and on page 274 of the history noted above. In the latter work we find also on page 204 the title *Transactions of the London Mathematical Society* instead of *Proceedings* of this society. In this case the title is the more misleading since the number of the volume is also incorrectly stated as 20 instead of 22.

It is true that the said *Séances* really were a journal and the said *Proceedings* really involve what is commonly called transactions, but the work of the beginner is apt to be greatly increased by a failure to give exact references and it is the beginner who should be especially encouraged to look up references. If such a reader fails to find a journal which bears the exact title given in the reference he seldom looks further.

While a study of the history of mathematics doubtless tends towards the formation of clearer mathematical concepts it is evidently necessary for the student of this history to distinguish carefully between the good and the bad in ancient methods. Some of the ancient methods which may appear to be praiseworthy for the time when they originated would be questionable and perhaps even intolerable if they were used in our modern textbooks. Possibly the ancient Greek proof of the fact that $\sqrt{2}$ is not a rational number belongs to this category since it is special and does not appear any easier than the following more general proof, which is based upon the elementary fact that if a rational fraction is reduced to its lowest terms than every integral power of this fraction is also in its lowest terms.

Suppose that $\sqrt[n]{m}=c/d$, where c/d is reduced to its lowest terms and d is not equal to 1. By raising both members of this equation to the n^{th} power it results that $c^n/d^n=m$, and since c^n/d^n is reduced to its lowest terms m can not be an integer. This known proof establishes at one stroke the existence of an infinite number of irrational numbers if we assume the existence of at least one real n^{th} root of every positive integer. To the extent that a knowledge of the history of mathematics leads us to prefer old historic methods to equally simple more general methods it is positively injurious.

Young teachers who study the history of mathematics with the laudable purpose of increasing their efficiency in the class-room should

bear in mind that there are exceptions to the rule that the mathematical development of the student is similar to the mathematical development of the human race. The modern student can not afford to acquaint himself with all the special and crude methods of the ancients before becoming familiar with the more powerful modern methods. The history of our subject is useful to the teacher provided he uses it to suggest methods rather than to supply these methods.

One of the most important questionable points in a general history of mathematics is the emphasis, or the lack of emphasis, on mathematical insight into the questions under consideration. It is evident that statements which have no mathematical sense such as the following: "In 1869 C. F. Geiser showed that 'the projection of a cubic surface from a point upon it on a plane of projection parallel to the tangent plane at that point, is a quartic curve; and that every quartic curve can be generated in this way," which is found on page 318 of the history noted above, should be avoided as far as possible. Similarly, authors should aim to avoid statements which are apt to be misunderstood because additional data must be supplied before they have any real significance, such as the following: "Newton uses his formulas for fixing an upper limit of real roots; the sum of any even power of all the roots must exceed the same even power of any one of the roots," which is found on page 202 of the same work.

There are, however, many statements which are perfectly accurate and yet fail to bring out the real mathematical situation. As regards modern developments some such statements can scarcely be avoided in view of the fact that details would involve an almost endless amount of explanations, but such details can be more easily supplied as regards ancient mathematics. For instance, the following theorem relating to the addition of the digits of a positive integer is found in various general histories of our subject. If any three consecutive positive integers, of which the largest is divisible by 3, are added together there results a number which is either 6 or reduces to 6 by the successive addition of its digits. The full significance of this theorem becomes clear only after considering it as a special case of the theorem that numbers which are congruent modulo 9 constitute an invariant with regard to the operation of adding digits, and observing the connection between this theorem and the ancient rules relating to "casting out the 9's."

We shall direct attention here to only one more questionable historical statement which appears on page 175 of the history to which we referred several times above, and reads as follows: "The new feature introduced by Descartes was the use of *an equation with more than one unknown*, so that (in case of two unknowns) for any value of one unknown (abscissa), the length of the other (ordinate) could be computed." From the words in italics one would naturally infer that

the emphasis was to be placed on the fact that Descartes used equations involving more than one unknown. On the contrary, the emphasis should be placed on the functional relation between the unknowns.

Equations with more than one unknown are very old in mathematics. In fact, it is well known that statements equivalent to such equations appear on one of the oldest fragments of papyri. In modern notation these equations have been expressed as follows:

$$x^2+y^2=100 \qquad y=\tfrac{3}{4}x.$$

A considerable part of the well known "Arithmetica" by Diophantus relates to equations in two unknowns and the Hindus used equations with more than one unknown, distinguishing them by colors, as the black, blue, yellow, red, or green unknown. As regards the expression of functional relations Descartes' work is well known to have been epoch-making.

In the present state of our knowledge of the history of mathematics it seems almost impossible to avoid questionable statements in works which aim to cover the entire field. The suggestions here offered relating to the other side of questions involved in various such statements may serve to arouse interest in a few important historical matters, especially on the part of those who enjoy the clash of views in a friendly combat.

THE EARLIEST PRINTED ILLUSTRATIONS OF NATURAL HISTORY

By Professor WILLIAM A. LOCY
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IN 1475, soon after the completion of the first quarter-century of printing, there appeared in Augsburg a popular book on natural history illustrated by woodcuts of animals and plants, some of which bear internal evidence of having been drawn from nature and of having been especially prepared for this book. Under the archaic title "Das Puch der Nature" by Conrad von Megenberg we have the prototype of illustrated treatises on natural history and popular medicine. It stands alone and is not genetically connected with any other; nevertheless it was the first of its kind, and perhaps it served as a model for other illustrated books of similar purpose which were published in Germany within the next ten or fifteen years. Conrad's book of nature passed through six editions before the year 1500 and enjoyed a wide circulation; we might even speak of it as one of the best sellers of the period, and thus the venture of the enterprising publisher, Hans Bämler, justified itself.

Since the book was the first to contain printed pictures of animals and plants it is of especial interest and challenges examination, not alone for philological study of the old dialect (Bavarian-Austrian) in which it is printed, but more especially as representing the scientific aspect of the period.

Another book, the "Gart der Gesuntheit" ("Herbarius zu Teutsch," etc.), published in Mainz in 1485, surpasses all others in the quality of its illustrations even up to the herbal of Brunfels published in 1530. This statement is so much at variance with the commonly expressed opinion of well-known writers of biological history (Sachs, Greene, Miall and others) that it seems desirable to reexamine the originals of each of these books from the standpoint of content and quality of illustrations. Both books are very rare and have been accessible to few naturalists. One bibliographer, Dr. Jos. Frank Payne, has (1902) discerned the unique position occupied by the Gart, "the publication of which (he says) forms an important landmark in the history of botanical illustration, and marks perhaps the greatest single step ever made in that art. It was not only unsurpassed but unequaled for nearly half a century." Dr. Payne does not comment on the few pictures of animals in the "Gart der Gesuntheit" but they are equally notable.

The book of nature and the "Gart" (for this title see below) have not received the notice of which they are deserving partly because attention has been diverted from them by the notice given to the Hortus Sanitatis which was published in 1491 and in many editions thereafter. The "Hortus Sanitatis" belongs to the same family of publications as the "Gart der Gesuntheit," but on account of its size, its numerous illustrations (1066), its later date of publication and its great popularity, it has been natural to assume that the "Hortus Sanitatis" represented the highest development of this class of books, and as a consequence, the two earlier (and much rarer) books have been passed by lightly and much greater attention given to the "Hortus Sanitatis."

The book of nature (1475) and the "Gart" (1485) not only antedate the Hortus Sanitatis but they are superior to it in several particulars; as already mentioned this superiority is especially marked in the better class of illustrations of the "Gart." These two early printed books represent a forward trend of the human spirit and should come under separate consideration. If ever we are able to gage the thought-life of the later Middle Ages, and especially of that interesting period of intellectual development just preceding the full bloom of the Renaissance, it must be accomplished by a study of the publications of the period. Accordingly, let no one assume that these books are merely curiosities of antiquarian interest.

The books of the time which have claimed most attention from scholars show another phase of the mental life of the period—that of the mystical-minded scholar and the theologian whose writings were more subjective in type, while Conrad's book, as well as the "Gart," represent the more objective or scientific attitude of mind. These two currents of mental life ran parallel, but at this time the instinct for creation through subjective methods was more conspicuous and the scientific attitude was undeveloped if not primitive.

The literary output of the period was more diversified than one might at first suppose. Besides Bibles, books of devotion, the famous "City of God" of Augustine, other religious writings and also legal treatises, a reader of the period found to hand printed copies of secular writings—some of belles-lettres and others of diversion: Dante, Petrarch, Boccaccio, Chaucer, Aesop's fables, the Bidpai stories showing affinities with the "Arabian Nights," Breidenbach's travels, the "Dialogues of the Creatures," "Reynard the Fox," "Romaunt of the Rose," etc. All these lay outside the field of the scientific and realistic books which were embodied in medical treatises and nature books.

Also dealing with nature (as well as other subjects) were such writings as the huge encyclopedias of Vincent of Beauvais, the "Properties of Things" by Bartholomæus Anglicus and the "Liber de naturis rerum" of Thomas of Cantimpré (the latter being the original of

Conrad's book of nature). Furthermore, it should be remembered that the printing presses were turning out on a relatively large scale the remains of classical and early mediaeval learning. Among these may be mentioned the scientific writings of Aristotle, Theophrastus, Pliny, Dioscorides and Galen.

But the book publishers of the period were desirous to stimulate a wide market for the sale of their wares and did not depend wholly on curiosity and mental interest. In the Latin preface of the "Hortus Sanitatis," published in 1491, there is a clever appeal to the commercial instinct. The writer, or compiler, says that he has been moved first and foremost by compassion for the poverty of those sufferers who have not the means to hire doctors and apothecaries and that by the teachings of the book these persons "with quite small expense to themselves will be able to compound helpful remedies and perfect medicines." This gives it the character of a book on popular medicine intended for the people. Another feature had more influence on the thought of the time; by pictures and descriptions, the attention of the people was directed to the productions of nature and information was spread regarding animals, plants and minerals. As Klebs says, "almost the entire structure of modern (biological) science rests on such humble beginnings." These books gathered what the monastic student had "milked," often uncritically, from the brain of the ancients and added comments and observations of their own. These additions mark the onset of inductive science. On the whole, the "Book of Nature," the "Gart" and other similar books represent a phase of the struggle to get away from the mystical and the subjective and to arrive at independent observation of nature. This was the call of the human spirit to engage in objective studies to which some types of mind are temperamentally inclined.

Conrad von Megenberg's "Puch der Nature"

This nature book was a German translation, with some changes, from the Latin "De Naturis Rerum" of Thomas of Cantimpré. The original was completed by Thomas about 1248, and translated by "Cunrat von Megenberg" a hundred years later. It was a complete review of nature and the first book of its kind of the Middle Ages. The German translation existed in manuscript for 125 years before it was first printed in 1475. That it was popular and widely circulated in manuscript form is attested by the numerous manuscripts in existence. Pfeiffer mentions 17 copies of the German translation in the library at Munich, 18 are reported from Vienna and many copies are known in other continental libraries.

In its printed form the book is now very rare. There are two copies of the first (1475) edition in the United States, both in the J. Pierpont Morgan library at New York. Through the courtesy of Mr. Morgan and

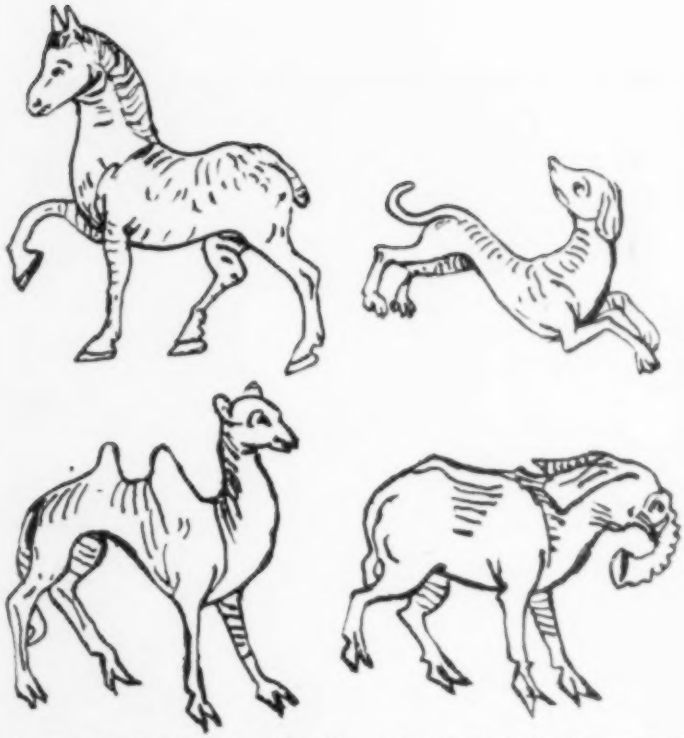

FIG. 1. TRACING OF FOUR FIGURES FROM A FOLIO PLATE OF TWELVE QUADRUPEDS. PUCH DER NATURE (1475). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

FIG. 2. TRACING OF THE FALCON FROM A PLATE OF THIRTEEN BIRDS. PUCH DER NATURE (1475). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

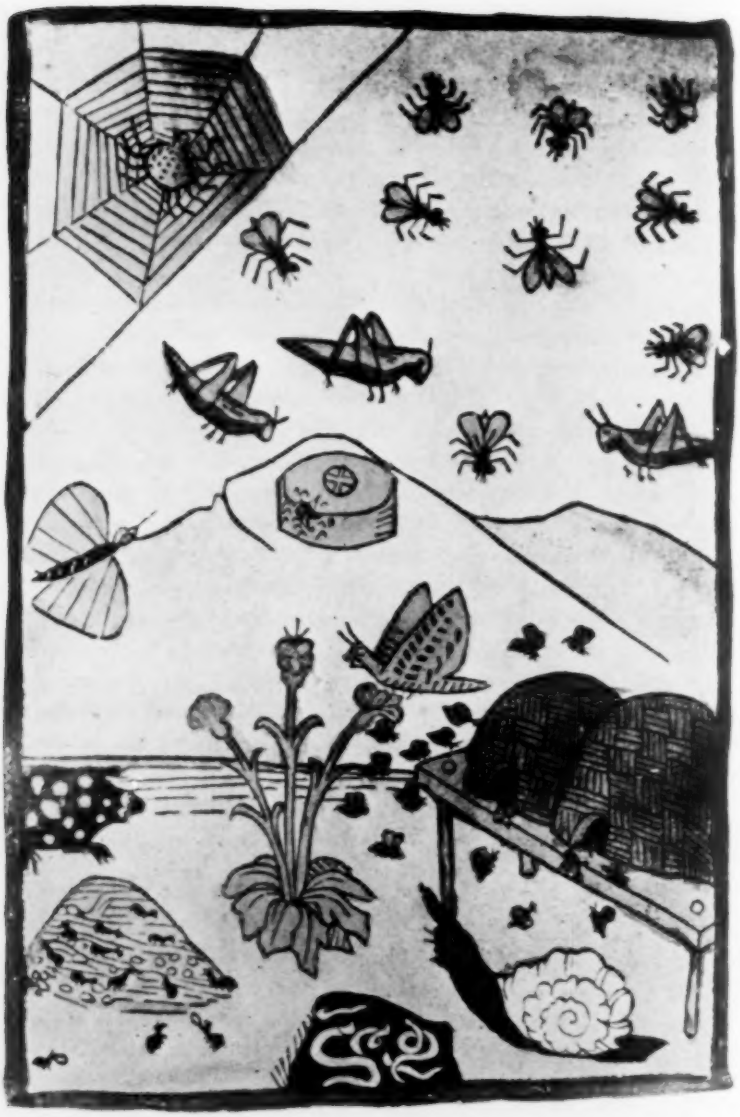

FIG. 3. PHOTOGRAPH OF A FOLIO PLATE OF INVERTEBRATES. PUCH DER NATURE (1475). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

his librarian I have had the opportunity of examining these books and taking photographs of the plates.

The short foreword, which was probably inserted by the publisher, telling the scope and the source of the book is as follows:

> Here follows the book of nature which treats first of the peculiarities and nature of man, then of the nature and the properties of the heavens, of beasts, of birds, of plants, of stones and of many other natural things. And upon this book a highly learned man worked for fifteen years collecting for his use from the following named sacred and secular teachers, poets and other approved doctors of medicine, such as Augustine, Ambrosius, Aristotle, Basil, Isadore, Pliny, Galen, Avicenna, etc., and many other masters and teachers. Out of these and others he read, made excerpts and compiled the book. Which book Master Conrad von Megenberg transferred from Latin into German and wrote it out. Here is a useful and entertaining material from which every man can learn many unusual things.

Among the several other authorities cited in the book, but not mentioned in the preface, is the "Physiologus."

In its original form, therefore, it purported to be merely a compilation and not a book of original studies. After fifteen years of labor Thomas of Cantimpré had completed the "De naturis rerum" and Conrad merely translated it. The German translation was repeatedly printed and widely distributed, while the original remains unpublished to this day. A curious turn of fate, as remarked by Sudhoff who says further, that the original Thomas, "in spite of all its faults and errors, had always served as an important document of medieval science and deserved publication certainly more than many another work."

Conrad's translation was not made directly from the text of Thomas, but, as Haupt has shown, from a working over and rearrangement of Thomas by Bishop Albert of Regensburg.

Conrad, the translator, was a cleric and teacher, who after various vicissitudes of life, became Canon at Regensburg. Evidently he was a lover of nature and had written a book on the world (Sphæra) and another on the "Gestelt der Welt." In translating the book of nature he says he rearranged and added to the book as well as omitted some points. Indeed, some of the manuscripts of Thomas contain an account of 193 animals not found in the translation (Carus), but there still remain 267 animals commented upon. He seems to have improved and added to the plants (Meyer). From time to time, he makes original comments, either expressing doubt of some statement or adding a remark of his own—introducing what he has to say by "I also Megenberger says"—but these comments are not of weighty importance.

Evidently the manuscript used by Conrad did not contain the author's name since he expresses doubt as to the writer of the Latin book, "whether Albertus Magnus or not, I do not know." The source of the book, however, is now well established.

FIG. 4. PHOTOGRAPH OF ONE OF THE TWO BOTANICAL PLATES. PUCH DER NATURE (1475). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

A complete copy of Conrad's book should contain 292 folio leaves and twelve plates of woodcuts. The two copies of 1475 which I have seen in the J. Pierpont Morgan library are rather handsome volumes as to format and printing. They were derived from the library of William Morris. Each copy contains the twelve folio plates and is nearly complete as to text. This is somewhat notable, since Hugh William Davis says that five of the plates are missing in the copy of the first edition in the British Museum. All cuts of both books in Mr. Morgan's library are colored alike in detail: accordingly, I presume that they were both done by the same hand or that there was a conventional type of coloring prevailing at that time.

The descriptive part of the book is disappointing. The art of description rests on good observation and at this period independent observation had not been developed. The text is chiefly a series of brief quotations from the writers of classical antiquity and the Middle Ages—Avicenna and Averroës (1198) being among the most recent. The excerpts are mainly folk stories and trivial observations about animal behavior. The book is comprehensive in range but the largest part of it is devoted to animals. In relatively brief compass, the text preserves for us the medieval lore about animals, plants and stones, but it is not descriptive science. I have not found a systematic or methodical description of any animal, but only quotations beginning "Aristotle says, Pliny says," etc. A few authors are cited under each title. Habits and behavior are spoken of but there is no description of appearance, color form, etc. Among flowers, rarely is the color of the flower mentioned (as frequently it is in the "Gart"). The comments on particular objects vary in length from seven lines up to two or three pages. Frequently one account occupies from one quarter to one half a page.

The general tone of the writing is shown by the following slightly abbreviated quotation about the lion. This is one of the longer (but by no means the longest) accounts and answers for the others.

> The Lion is king of all other animals, as Jacobus and Solinus say. This beast has nothing false, untrue or cunning about him. He is so hot by nature, that one may think he is always in a fever. The lioness always at first gives birth to five whelps,then to four, then to three, thereafter to two and the fifth time to one only. After that she is barren. Augustine says, when the cubs are born, they sleep three days until the father comes; he cries very loud over them, and being frightened by the noise they awaken. The lion fears the sharp sting of the scorpion and flees from it as from a deadly enemy. He fears also the rattling of wheels as they turn on the wagon, but he fears fire the most. Solinus says, that the lion is not easily angered, but being enraged, he seeks the offender (Zornmacher) and tears him to pieces. He never attacks man willingly, and only in great hunger. Adelius says, when the lion sleeps, he has his eyes open. When he travels, he blots out his footsteps with his tail, so that the hunter may not find him. Also Pliny says, that lions are friendly among themselves and do not fight. Aristotle says,

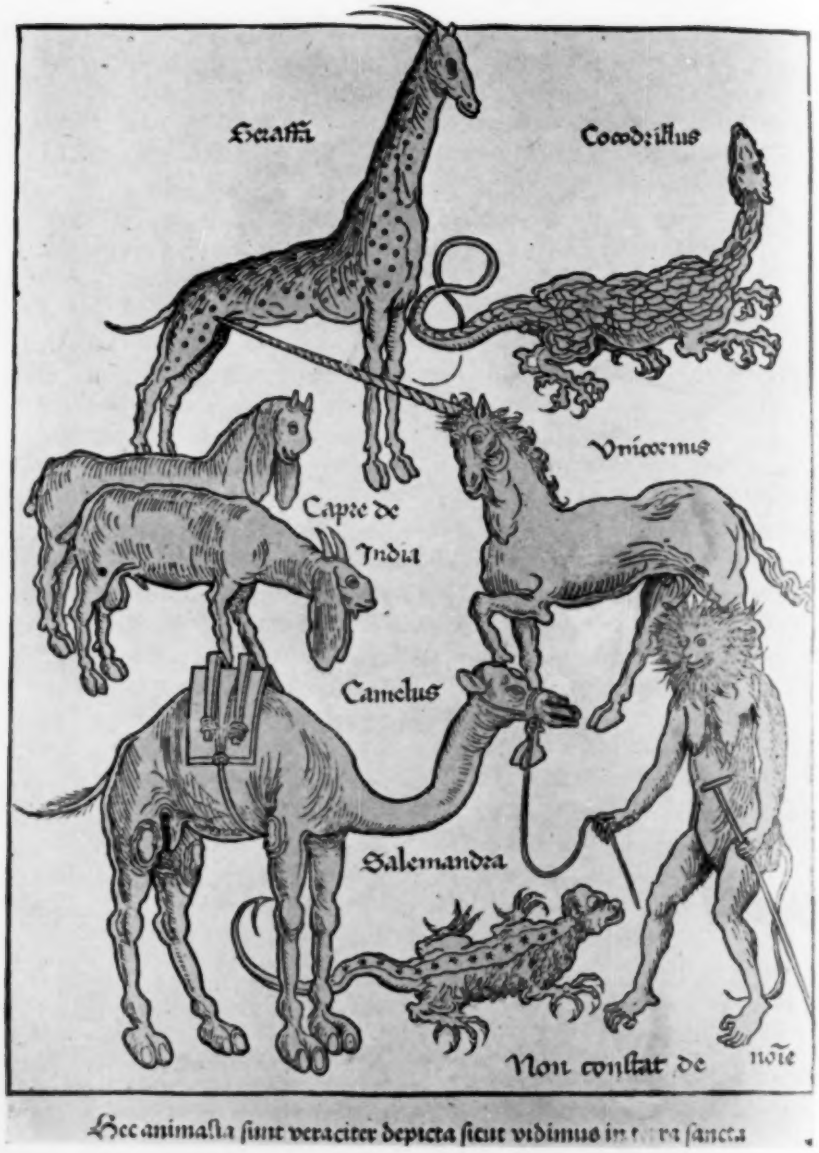

FIG. 5. PHOTOGRAPH OF A FOLIO PLATE OF ANIMAL FIGURES. BREIDENBACH'S TRAVELS (1486). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

the lion hides his bone the same as the dog. When in hunger, he draws with his tail a large circle on the ground and roars loud and frightens other beasts so they do not dare to come within the circle. He scorns the eating of yesterday and the remains of his former feasting. Some say that the lion dies of his own anger, he is so violent. The lion willingly captures the wild ass and chases him in nature. Ambrose says, when he is sick, if he catches an ape and eats him, he becomes well. When the lion drinks dog's blood, he becomes well. Solinus and Pliny say, that when the lion holds his tail quiet, he is mild and friendly; but that is seldom. . . . . Pliny says, that lion's flesh and especially the heart is good for people to eat; those who are too cold by nature, when they eat lion's flesh, will become warm. The lion's bones are so hard, that one can strike fire with them as with a flint. The lion's fat is an antidote against poison. When a man annoints himself with wine and lion's fat, it drives away all beasts from him, also snakes. The lion's fat is of warmer nature than that of any other animal. The lion is continually afflicted with a quartan fever so that he desires especially the flesh of apes, that he may become well. Lion's fat with oil of roses frees man's face from freckels, clears it and keeps it so. The lion's neck is thick and the flesh of the neck is cartilaginous, so he can not raise his head backwards. Alexander says, that the lion has great strength in his breast, in his fore feet and in his tail. *Leon* in Greek is a king, therefore is this beast called *leo*, because he is the king of all other beasts. The lion is warmer by nature in the fore part of the body and colder in the hinder part; also the sun is in the constellation of the lion. Aristotle says, that of all animals the lion has no marrow in its bones except in the femur. Therefore his bones are harder than those of any other animal, except the dolphin. The lion's intestine is like the dog's intestine. The lion is feverish in the summer, but is well in the winter. He also becomes feverish before the face of man.[1]

The duck is dismissed with seven lines, while the account of the hen is unusually long, occupying three and one-half pages. Regarding the ass, "Pliny says, it has white milk . . . that Nero was nourished on ass's milk."

Each of the twelve parts into which the book is divided is preceded by a general introduction in which one often finds moralizations and expression of theological views. In various places Conrad makes uncomplimentary allusions to the profligate priests (üppigen Pfaffen), who like the ass are weak when they should carry the cross and strong when they are unchaste. The bishop is compared to the peacock and also to the raven. It is merely a conjecture, but the great rarity of the book may be partly owing to these attacks on the priests. These allusions would naturally arouse the hostility of the very powerful theological bodies and, not unlikely, lead to attempts to suppress the book. In looking over the Index Librorum Prohibitorum, however, I have not found the "Book of Nature" on the prohibited list.

The illustrations in Conrad's book of nature are on twelve folio

[1]I am indebted to my colleague, Professor James T. Hatfield, for assistance in translating some of the more obscure passages.

Reptilia multa se sup humū simul solaciabantur ad so=
lem sed basiliscus id est serpens venenosus ut supra
dictum est in dyalogo quadragesimoprimo in mediū
exiliit clamans ·quis in duello mecum salire poptat veniat
et pugnabo cū eo Testudo autem in medio processit cum ipsa
pugnatura Dum autem simul pugnarent basiliscus cupie=
bat eam mordere et toxicare · sed testudo trahebat et caput
et pedes in concham q̄ non poterat eam tangere Postea ve=
ro extrahebat et basiliscum cum dentibus et vngulis aculea=
bat·fit enim victus anguis erubuit Paululum post denuo se
fortificauit · et volens se excusare q̄ erat turpiter victus ait ·
volo me vindicare · si est inter vos aliquis preliator ve=

FIG. 6. ANIMAL FIGURES IN THE DIALOGUS CREATURARUM (1480). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

plates, inserted as leaves separate from the text, one plate at the beginning of each division of the book. The wood-cutting is coarse, and the drawings are by no means so good as those of the "Gart." So far as known these sketches have no forerunners; they are not traditional figures copied from earlier manuscripts, as was frequently the case of illustrations printed before 1530. On ten of the twelve plates there are not less than eighty-six figures of animals (some of the smaller repetitions not being counted). The remaining two plates contain nineteen figures of plants and trees.

The illustrations vary in quality—when the figures are of domestic animals, so that the designer could see examples, the figures are rather good—see the dog and the horse in Fig. 1. The goose, dear to the heart of the German for festive occasions, the falcon (Fig. 2), the woodpecker, the peacock, although crude are evidently drawn from nature. The exotic animals, however such as the camel, the lion, and especially the elephant (Fig. 1), with cleft-hoof and schematic trunk, are very bad—the designer had no specimens to look at. The fishes are not well drawn. The general appearance of the plates with a rough border is shown in Figs. 3 and 4. The plate of animals (Fig. 3), shows several insects—ants, bees, grasshoppers, butterfly,—a spider, a snail, etc. The plate of plants (Fig. 4), shows the grape vine, the apple tree, the pear tree, and other pictures less easily recognizable.

The figures in the "Book of Nature" are the earliest printed pictures of natural history—they mark the beginning of scientific iconography. Arnold Klebs, in his Incunabula Lists (1917), speaking of the "Herbarium" of Apuleius Barbarus, Rome, 1483 (and 1484), says: "Its illustrations, crude formalized pictures of plants, are, with possibly one exception, the earliest ones in a printed book." He does not mention the "Book of Nature," but certainly there were two plates of botanical illustrations in this book published in 1475. The rarity of Conrad's book, and especially of perfect copies, accounts for the little notice it has received and also for misconceptions regarding the number of plates which it contains. Mrs. Arber in her very fully illustrated treatise on herbals reproduces one of the plates from the "Puch der Nature" (1475), and speaks of it as "the single plant figure" with which the book is illustrated. Hugh William Davis, in "Early German Books" has already pointed out that five plates are missing from the copy of the first edition in the British Museum. For the second plate of botanical figures see Fig. 4.

The introduction of pictures into printed books of science was an important step. The preparation of cuts forced observation and sharpened it. Through this means attention was directed to details and observation was promoted. This was an entering wedge of independent observation at a time when observation was struggling for the right to exist. The preparation of the figures required greater accuracy

FIG. 7. PHOTOGRAPH OF A FOLIO PLATE OF ANIMALS. BARTHOLOMAEUS ANGLICUS (1486). ORIGINAL IN THE J. PIERPONT MORGAN LIBRARY

and some independent observation and these original efforts were allowed to stand. They did not provoke the hostility of the censors as did original comments. The pictures might pass, but expressions of independent opinion might be contrary to theological doctrine. The pictures of the "Gart der Gesuntheit" were so much more notable that further comment will be withheld until the next section.

It will be interesting for local color to compare figures of animals in contemporary books of different purpose. In connection with the special examination of the "Book of Nature," I also had for use in the J. Pierpont Morgan Library copies with illustrations of Breidenbach's "Travels" (1486); several copies of Bidpai (1486 and others); the "Dialogus Creaturarum" (1480 and others); Bartholomæus Anglicus, in Flemish (1486), and in English (1495); the former with good pictures of animals and plants, the latter with wretched ones.

The single plate of animal pictures in Breidenbach's "Travels" (Fig. 5) contains pictures that are superior as to drawing and as to woodcutting. Although there are some mythical animals represented, the camel and the giraffe are well executed and are evidently drawn from nature. William Morris says, in general, of many pictures in Breidenbach's book: "These woodcuts are remarkable, not only as the best executed illustrations in any medieval book, but as being the first woodcuts in which shading is used in masses and not merely to help the outline." In Bidpai ("Buch der Weisheit" and other titles) is a grotesque figure of an elephant with cleft hoofs and a long bovine tail and also a schematic trunk similar to the one in Conrad's picture (Fig. 1). In the "Dialogus Creaturarum" (1480), there occurs an elephant with the soliped hoof of the horse and with the horse's tail (Fig. 6). Now these are not pictures drawn for a scientific book but as representing the conception of these animals by designers of the time they are significant. The figures in the Flemish edition of Bartholomæus Anglicus (erroneously de Glanville), (Fig. 7), although published in 1486, far surpass those of the English translation, published in 1495, by Wynkyn De Worde. The plate of quadrupeds (Fig. 7), of birds and of plants of the Flemish edition show signs of observation from nature (note especially the elephant in Fig. 7). The figures in the English edition on the other hand are wretched caracitures—some of them being degraded copies of the figures of Conrad's book. Mrs. Arber published the plate of plants from the English edition of 1495, but the botanical plates in the earlier Flemish edition are much superior.

For readers who may be interested in looking over the literature relating to the "Book of Nature" and its translator, I make note of the chief references consulted. Besides the original edition of 1475, I have made use of the analyses of the book by Choulant ("Anfänge wissenschaftlicher Naturgeschichte und naturhistorischer Abbildung in

Acorus geel lilien Cap·xxj·
Coms vel ſpatella latine·Glaſpatella vel
nerea vel pyper·xpiñ grece·Arabice vero
Maeg vel dogog vel zweg

FIG. 8. PHOTOGRAPH OF THE YELLOW FLAG. GART DER GESUNTHEIT (1485). ORIGINAL IN THE SURGEON GENERAL'S LIBRARY

christlichen Abendlande," 1856); by Meyer ("Geschichte der Botanik," 1857); by Sudhoff ("Studien zur Geschichte der Medizin," 1908) and the bibliographical notice by Hugh William Davis in "Early German Books" in the library of G. Fairfax Murray, 1913. In 1861, Pfeiffer published (without illustrations) the entire book under the title "Das Buch der Natur, von Konrad von Megenberg, Die erste Naturgeschichte in Deutcher Sprache." This is a study of the book from the philological standpoint and is accompanied by a dictionary of some 250 pages. There is also a metrical translation in Flemish, and in rimed verse, entitled "Naturen Blœme." This was made by Jacob de Mærlandt who died in 1300, so that his translation preceded that of Conrad. The first part of the Naturen Blœme was published in 1856 and the complete work in 1878.

The "Gart Der Gesuntheit"

While the "Book of Nature" had a long history in manuscript, the German translation going back to 1349, the Gart, on the other hand, although a compilation, seems to have been a product of the time—arising about the printing house. It was thus an expression of publisher's enterprise—the excerpts being chiefly made by a physician who acted as the scientific collaborator, and the blocks being cut under the eye of the publisher. No anticipations of the illustrations nor of the text are known, except that the text is pieced together out of earlier writings on nature. From the account in the preface it would appear to have been the product of the combined labors of the original designer, a master of medicine and a skilful artist. The following quotation is taken from Mrs. Arber's translation of the preface:

> Since, then man can have no greater nor nobler treasure on earth than bodily health, I came to the conclusion that I could not perform any more honorable, useful or holy work or labor than to compile a book in which should be contained the virtue and nature of many herbs, and other created things, together with their true colors and form, for the help of all the world and the common good. Thereupon I caused this praiseworthy work to be begun by a Master learned in physic, who, at my request, gathered into a book the virtue and nature of many herbs out of the acknowledged masters of physic. . . . . But when, in the process of the work, I turned to the drawing and depicting of the herbs, I marked that there are many precious herbs which do not grow here in these German lands, so that I could not draw them with their true colors and form, except from hearsay. Therefore I left unfinished the work which I had begun, and laid aside my pen, until such time as I had received grace and dispensation to visit the Holy Sepulchre, and also Mount Sinai. . . . . Then, in order that the noble work I had begun and left incomplete should not come to nought, and also that my journey should benefit not my soul alone, but the whole world, I took with me a painter ready of wit, and cunning and subtle of hand. And so we journeyed from Germany. . . . . In wandering through these kingdoms and lands, I diligently sought after the herbs there, and had them depicted and drawn with their true color and form. And after I had by

FIG 9. PHOTOGRAPH OF THE WHITE LILY. GART DER GESUNTHEIT (1485). ORIGINAL IN THE SURGEON GENERAL'S LIBRARY

God's grace, returned to Germany and home, the great love which I bore this work impelled me to finish it, and now, with the help of God, it is accomplished. And this book is called in Latin, *Ortus Sanitatis*, and in German, *gart d'gesuntheyt*.

Considerable confusion has arisen as to the distinctive title by which this work should be known. Choulant, who in 1857, gave the first complete analysis of the book, called it the "smaller Hortus" and thus it came to be confused with the "larger," or true "Hortus Sanitatis" which was first published in Mainz in 1491, and became widely distributed in later editions. Although the "Hortus Sanitatis" owes something to the "Gart" as a forerunner of the same type, it differs in language and in extent—being much more voluminous and having 1066 figures, while the "Gart" originally had a total of 397 illustrations. Most of the pictures of the "Gart" were copied and recut for the "Hortus Sanitatis," but they were degraded and of much lower quality. The "Gart" was originally prepared in German; "the Hortus Sanitatis" was in Latin, but not a translation of the "Gart" although modeled after it and showing generic resemblances to it. Neither was the "Gart" a German translation of the Latin "Herbarius" which preceded it by one year (1484). The text and, notably, the illustrations are different, not only more numerous (150 in the Herbarius and 397 in the "Gart") but of superior quality.

The extant copies are rarely complete and the title page is frequently missing; but, whatever the title on the fly leaf of the various issues and variants of the "Gart"—"Herbarius zu Teutsch," "Ortus," etc., there occurs an unvarying title in every preface—"And this book is called in Latin Ortus Sanitatis, in German ein Gart der Gesuntheit." (From the first Mainz edition, 1485). Arnold Klebs in his Incunabula Lists (1917) has greatly clarified the matter by a complete analysis of what he calls the Hortus family, showing the family to consist of some forty issues of related books—the "Hortus Sanitatis" of 1491 being the central member and the most extensive. The original edition of the "Gart" is the most important for determining the quality of its illustrations and any confusion of title should by all means be avoided. The suggestion of both Sudhoff and Klebs to designate the work by the short title "Gart" is opportune since this gives a distinctive title that can not be confused with that of any other member of the "Hortus" family. The "Gart" is the original of the entire "Hortus" family. The name of the designer of the book is not known but the scientific collaborator is believed to have been Johann de Cube (mentioned on page 127 near the end of chapter 76) and identified by Sudhoff with Johann de Wonnecké, a practicing physician of Frankfurt at the end of the fifteenth century.

A complete copy of the "Gart" of 1485 should contain 356 folio

FIG. 10. PHOTOGRAPH OF THE FOX. GART DER GESUNTHEIT (1485). ORIGINAL IN THE SURGEON GENERAL'S LIBRARY

leaves, 435 numbered chapters with 386 pictures of plants (one repeated) and eleven of animals (one repeated). The copy placed at my disposal at the Surgeon General's Library in Washington has 320 leaves, and 427 chapters but lacks a few intervening leaves. I am greatly indebted to Colonel Garrison and others of the library staff for assistance and opportunity to photograph the plates of the book. Choulant mentions thirteen issues of the "Gart." The number of illustrations varies in the different issues—one edition, with the addition of genre-pictures, has as many as 542 pictures (Klebs). Choulant says that the pictures of the pirated edition, printed in Augsburg five months after the Mainz edition and attributed to the press of Anton Sorg, are for the most part better than those of the original edition. I have been much puzzled by this statement of Choulant as to the quality of the pictures, and, owing to the recognized thoroughness of Choulant's work, am reluctant to question it. However, the book to which Choulant refers (Hain 8949*) is assigned by recent bibliographical experts to the press of Schönsperger. I have recently seen a perfect copy of this in the Newberry Library of Chicago, which is not listed in the Census of Fifteenth Century Books owned in America. It is dated at Augsburg, August 22, 1485, but the name of the printer is not given. As determined by reference to Haebler's *Typenrepertorium*, the book is printed in Schönsperger type, No. 1, and is 120 as to size. There remains the question of the quality of the illustrations—those in the book of the Newberry Library are smaller and inferior to those of the original Mainz edition. I have also seen the Augsburg edition of March, 1486, from the Schönsperger press, derived from the collection of the late Theodore L. De Vinne, and now owned by the John Crerar Library of Chicago. This is a smaller book, printed in two columns instead of full-page, and its illustrations are much smaller and much inferior to those of either the Mainz or the Augsburg edition of 1485.

It is in reference to the illustrations that the "Gart" is especially notable. The pictures are chiefly those of plants, numbering 386, while there are only eleven pictures of animals. The pictures vary in quality, but seven pictures of animals and five or six of plants are of unique perfection among the early printed illustrations. The picture of the yellow flag (Acorus) (Fig. 8), of the white lily (Fig. 9) and of the fox (Fig. 10) are fine examples of drawings from nature. The cut of the yellow flag has been published full-size by Dr. Payne and by Mrs. Arber, but, so far as I am aware, the figures of the white lily, and of the fox and other animals have not been reproduced.

No one can examine the original cuts and retain any doubt that they were drawn from nature by a skilful artist and a careful observer. The lines of the woodcuts are coarse but the few best sketches rival

those published by Brunfels (1530) and Fuchs (1542). The best figures in the "Gart" show the highest level to which botanical and zoological illustrations attained not only in the fifteenth century but also in the first third of the sixteenth. Fifty-five years before the renovation of botanical illustration by Brunfels, and sixty-seven years before the publication of the figures of Fuchs, the best pictures of the "Gart" stand out as beacon lights in the development of scientific illustration. They are of singular importance in the history of scientific iconography and are deserving of great praise. An unpredjudiced examination of them can not fail to modify the incorrect estimate as to the quality of all printed illustrations of natural history before those of Brunfels.

In the botanical books that followed for fifty-five years from the printing presses of various countries, the pictures of the "Gart" were copied and recopied, but in the process they were degraded and conventionalized, so that one can get a correct impression as to quality only by examining those of the first Mainz edition. Even so careful and original a student as E. L. Greene, whose "Landmarks of Botanical History" shows great thoroughness, maturity of judgment and first-hand acquaintance with the sources, repeats the generally accepted opinion, saying (p. 195): "To a generation that had been accustomed to such books as the 'Hortus Sanitatis,' filled with the most wretched caricatures of plants in place of true representations of them, this great book of Fuchsius must have appeared as nothing less than luxurious" and again, (p. 167): "Even 40 or 50 years before these fathers of plant iconography there were printed copies of the 'Hortus Sanitatis,' and its German version 'Gart der Gesuntheit' illustrated by some 500 wood engravings of plants. Doubtless the wretched character of these first printed plant pictures, along with the great popularity of the books containing them, were what moved Brunfels to undertake the publication of the 'Herbarium Vivæ Icones.'" Here a direct reference is made to the "Gart der Gesuntheit" (the "Hortus Sanitatis" having 1066 figures, instead of 500). The criticism will apply to the degraded pictures of the "Hortus Sanitatis" but not to the better pictures of the "Gart." The explanation of such an unwarranted sweeping conclusion is doubtless to be set down to the great rarity of the "Gart," and to the belief that, since the "Gart" was an earlier publication of the same type, the pictures of the "Hortus Sanitatis" can be taken as showing the quality of the pictures of the earlier book.

No one can look at the pictures of the dodder, the yellow flag, the white lily, the fox, etc., and consider them as wretched caricatures; they rival the printed pictures in the herbals of Brunfels and of Fuchs as to quality and fidelity to nature.

GETTING MARRIED ON FIRST MESA, ARIZONA

By Dr. ELSIE CLEWS PARSONS

THERE are three towns or rather two towns and a suburb on First or East Mesa, Walpi, the Hopi town, with its suburb Sichumovi, and Hano or Tewa, a Tanoan settlement from the East, made, it is said, two hundred or more years ago.

It was from Yellow-pine, a young Tewa woman married for about three years that I heard most about Tewa wedding practices. Yellow-pine spoke English comparatively well, well enough to tell a story in English in about the same way as she would tell it in Tewa. This is her narrative:

"The boy goes to the girl's house at night to see her. If the girl's mother does not want him, she tells the girl. If she wants him, she says, 'You can talk[1] to him,' she says. (But if the girl wants the boy, even if her people do not want him, she can talk to him.) The boy tells his people; if they say yes, then the boy comes again and tells the girl. Then the girl makes *piki* [wafer bread, in Tewa, *mowa*], the narrow kind of *piki*, like sticks (*makana*). She makes *piki* all day. She piles it high, beginning early in the morning. At night the girl and her mother take the *piki* to the boy's house. The boy's people are happy and say, 'Thank you,' and give them meat. They bring it home. From that they all know that he is going to marry her. Now, any night, they take *piki* again to the boy's house, and the boy's people give meat. From then on they begin to get married. . . .

They grind corn every day until they fill ten or twelve boilers [store-bought tin boilers]. It takes a month to complete that work. They also prepare white corn to put in water for the boys to drink. Then they are ready. They go to the boy's house to tell the boy's people they will come in four days. The boy's people get things ready to eat. The girl tells her uncles [maternal uncles or kinsmen] and fathers [paternal kinsmen] to come to her house on the night they plan for. . . .

On this night they dress the girl in her *manta* [i. e. ceremonial blanket] and wheel her hair. Then they go to the boy's house where all the boy's people are gathered together, and where they have set out meat and bread and coffee. 'We have brought this girl to you to grind as much as she can,' say the girl's uncles. 'Is that so? All right. We are glad to have her,' they say. . . .

Next day, early in the morning, the girl starts to grind. She has to grind all day,[2] stopping only to eat. For three days the girl grinds. Early in

[1] At Zuñi, the New Mexico pueblo where custom is most like Hopi custom, "to talk to" is also the usual expression for courting.

[2] I. e., until about 4 p. m., the closing time of the Hopi work day.

the morning of the fourth day they wash the girl's head. The girl grinds once more and finishes. They [in the girl's house] make many bowls of blue corn meal, and they make *mowasi* (corn boiled and wrapped in corn husk). The girl's clanswomen come in to help. That night the girl's people take to the girl's house five or six boilers [empty] from which they are to give out meal to the boy's people, his aunts [father's sisters], uncles, and mothers [mother's sisters or kinswomen], meal and *piki* and on top *mowasi*. Whatever is left over is given to the boy's mother.

That day the boy's clansmen have brought out cotton to weave into a blanket for the girl. They take the cotton to the girl's house. Her mother thanks them, and puts meal for them in the bowl that held the cotton. The men take the cotton to the kiva to work on it. While they work, the girl has to stay on in the boy's house and do the cooking of the house and the sweeping, while they work for her in the kiva. . . .

When the men in the kiva start to make the white blanket, they take *piki* to them and white corn water to drink. And every day they take bread and meat. At the girl's house they are making heaps of meal and the girl's clanswomen are making *piki*, all night the women are making *piki*, and all night there is a meal set out for them. The next night they make *pigami* (a stew of samp and mutton).

A day or two later they take water to the girl's house and to the boy's house to get ready to make *piki* early in the morning. In both houses they make *piki* to take to the houses of the men who are working in the kiva for the girl. In that way they pay the men for making things for the girl.

Then the boy's mother tells the girl's mother in how many nights they are going to take the girl home again. They get ready, they cook for that night. . . . They put on the girl her blanket and moccasins. That night they cut the girl's hair on the sides.[3] The boy's mother and sisters take the girl to the girl's house. There, to thank them, are assembled the girl's uncles.

Early the next morning, they wash the boy's head [he has followed his wife], all the girl's mothers and father's sisters wash his head.

Four days later they make *piki* all day in the girl's house and towards evening they take it all to the boy's house. . . .

Afterwards, at any time, perhaps two or three years afterwards, the girl has ground in her house ten boilerfuls of corn, including one boilerful of white corn and one of sweet corn. After this grinding, the boy's people go to the girl's house and whitewash the walls and clean house. The next day the boy's mothers and father's sisters bring water to the girl's house. The next day, early in the morning, in the girl's house they start to make *piki*. They make *piki* and they grind meal all day. They fill up the baskets to take them to the boy's mothers. With a pan of beans the girl's mother goes first, the girl in her white blanket follows and the other women. The boy's people are waiting, they get happy. They go to the girl's house and eat. That is all, except that afterwards, at any time when the men who made

[3] Like the hair of Zuñi and Keresan women. Hopi women, married women, part the hair and with a string twist the locks on either side of the face. . . . That the Tewa women have thus preserved their own style of hairdressing is an interesting fact. Style of hairdressing and language are, as far as I know, the only distinctive traits, exclusive of religion or public ceremony, preserved by these Tewa immigrants whose town is within a stone's throw of the houses of their Hopi neighbors.

her things are going to dance, the girl dresses in her white blanket and takes the dancers *pigami*.[4]—It is hard work for us to get married.

A long time ago, it was not so hard. But now we get married just like Hopi, and it is much longer and harder."

It is quite likely, as Yellow-pine suggested, that Tewa marriage ceremonial was formerly more simple, as it is among other Pueblo Indian peoples. In Tewa folk-tales the ceremonial or etiquette of getting married is much the same as in Zuñi tale and practice[5] and probably in ancient Keresan practice.[6] The youth comes to the girl's house. She sets food out for him, he tells the parents what he has come for, they say that it is not for them to say, but for their daughter. (As Yellow-pine remarked, the choice is really with the girl.[7]) The youth leaves, to return another night with his bundle, his gifts of blankets, belt, and moccasins to the girl. If she accepts them, she carries in her turn a gift of corn meal to the young man's house, where she stays four days to grind. There on the fourth morning her head is washed. Then the couple return to live at the house of the girl's mother. A gift of apparel from the man, a gift of meal from the girl, her visit, a betrothal visit, so to speak, to the man's maternal house, the rite of head washing, and the return to the girl's maternal house—this seems to be the generic Pueblo form of wedding to which the Hopi and then the Tewa, in imitation, gave elaboration. Curiously enough, Spanish influence in the Eastern pueblos, Keresan and Tanoan,[8] has tended to a somewhat analogous elaboration, a case of similarity, we can but think, due to convergence.

The extent of the Hopi elaboration appears even more fully in another account of Hopi wedding practices given me by a Tewa man,

[4] At Oraibi, Voth notes that all the brides of the year appear in their white blankets at the close of the *niman kachina* or farewell performance in July, the most elaborate of the masked dances. ("Oraibi Marriage Customs," p. 246. *American Anthropologist*. II. 1900).

[5] Cp. Parsons, E. C. "Notes on Zuñi," pt. II, 302, 307, 322, 325. *Mem. American Anthropological Association*, IV, No. 4, 1917. Lack of weaving at present day Zuñi and the comparatively small amount there of clan cooperation would account in large part for the simpler way of getting married.

Second marriage is among the Hopi comparatively simple because no bridal outfit is to be made.

[6] Dumarest, N. "Notes on Cochiti, New Mexico," pp. 148, 149. *Mem. American Anthropological Association*, VI, No. 3, 1919.

[7] On the other hand I have been told that among old-fashioned people the girl's parents and uncle (mother's brother—note the significance of participation by the uncle to the theory of cross-cousin marriage, p. 265) would look for a boy for her. "My daughter, you will marry that boy," they would say to her. To be sure, "she might leave the boy they chose and choose her own boy," and, if her family were angry, she would go to live with some kinswoman.

[8] Cp. Parsons, E. C. "Further Notes on Isleta," *American Anthropologist*, in proof.

a Bear clansman married into a Hopi (Sichumovi) house and the father of a girl whose wedding was not yet completed, although she was the mother of a three months' old infant. The final gift of meal was not yet made. My Tewa friend had the wedding of his daughter Butterfly in mind, as he talked, I think, although he put his narrative into an impersonal form. Some of his narrative is supplemented by information from his wife, Butterfly's mother.

Whenever a girl finds a boy, the boy comes to see the girl's parents. After he comes, the parents ask what he wants. "I come to see about your daughter," he says. "I don't know about it," says the father of the girl, also the mother of the girl. "We will tell her uncles (*taamatö*, her mother's brothers, etc.), and see what they have to say" . . . The mother of the girl tells her uncles to come to her house. They come at the time she says. (There were six uncles who came in to talk about Butterfly). The mother of the girl says, 'I called you because there is a boy wants our child. I told him I had nothing to say until I called you.' An uncle may say, 'I don't think we want that boy to marry our niece (*tatiwaiya*, sister's child).' Or an uncle may say, 'Well, it is all right.' [In this case] the next time the boy comes, the mother of the girl says, 'I told my uncles. It is all right, they say. Tell your mother and father, and they will tell your uncles, and what your uncles say you tell us.' Then the mother of the boy will call in her uncles and tell them that the boy has been to the girl's house. 'Her mother and father said for me to call you and see what you think about it' . . . If it is all right, the girl's people take some food (*piki*) to the boy's house to let them know that the girl is going to marry the boy. This *piki* the boy's mother distributes to all members of her clan. . . . After this the parents of the boy have to look for buckskin, and for cotton to weave into the wedding blankets (*kwatskyapa*) . . . The girl's people begin to grind corn to fill ten bowls. (To help Butterfly, there were, besides her mother and mother's mother and mother's sister, one other close relative and five clanswomen). Then they say when they will take the girl to the boy's house; they tell the mother of the girl to tell the mother of the boy. The mother of the girl goes and tells the mother of the boy, and she tells all her uncles to come to her house and all her clanswomen (*nahimatō*) and all the aunts (*kyamatō*, father's sisters) of the girl and all the girl's father's brothers (*namatō*) i. e. clansmen. (When our girl married only my own two brothers came, but we asked all the Bear men. We can't tell who will come.)[9] The girl's aunts take some corn meal to the girl's house, in the evening, and the aunt[10] of the girl dresses the girl and puts her hair up in wheels. They all talk to the girl, each of them saying she must work at the boy's house and not be lazy. . . . They go to the boy's house, the girl's aunt goes first, carrying corn meal on her back, then the girl, then the girl's mother and then the girl's father, then the uncles, then the girl's brothers. They all go single file —[the usual Hopi formation for any formal group in progress]. At the boy's house they have prepared supper for all who are to come. They eat supper, they leave the girl there, they go back home. This night the mother of the boy takes care of the girl. Early in the morning the girl gets up to

[9] This is characteristic of all invitations to clanspeople, whether to join in a work party or a name-giving rite or other ceremonial occasion. All are asked; but only the closer relatives feel any obligation to come.

[10] The senior sister or cousin of the girl's father, her aunt *par excellence*.

grind corn. Across the place where the girl is grinding they hang a blanket or, nowadays, a wagon cover, so nobody may talk to her or the sun shine on her. They give her breakfast. . . . The boy's father's mother tells all her clanswomen to go to the boy's house, carrying water. The boy's mother goes around and invites her clanswomen to come to help her against the boy's father's clanswomen. Then they start to fight. (*Möungkipoh mowa*, female connection by marriage; *kipoh*, go to fight). [See p. 265 for explanation]. Then they go back home. . . . The girl grinds all day. The mother of the boy tells the girl when to stop grinding. They eat supper, they go to bed, and the mother of the boy takes care of the girl. . . . The first day the girl grinds white corn, the second and third days, blue corn, the fourth day, pop corn to be drunk in water. On the third day, in the evening, the mother of the girl begins to put up her meal to take to the boy's house. The father or brother of the girl are to take it to the boy's house. All night any of the townswomen may go to the girl's house to help make *piki*[11] as well as the girl's clanswomen, even clanswomen from other towns. . . . Early in the morning they wash the girl's head; first the mother of the boy takes down one wheel of the girl's hair and washes, then the father of the boy takes down the other wheel and washes, then the boy's sisters wash and then his clanswomen.[12] [They wash, as usual, with jucca root suds, dipping the suds on the head with an ear of white corn that is completely kernelled, one of the ears people refer to as "mother" and which is used on many ceremonial occasions. The dipping is quite formal, the head touched lightly four times, when a few words of prayer may be said. A thorough washing follows. After the washing, corn meal is rubbed on face, arms, and body, and meal is given to the person washed to take out and sprinkle, perhaps in a shrine, or on the eastern edge of the mesa, with a prayer for long life and prosperity.] They dress the girl's hair in a roll along each side of the head.[13]

After the head washing they eat the *piki* brought from the girl's house and the *pigami* made in the boy's house and for which his father has killed a cow. Other *piki* is given later in the day to the boy's clanswomen who come in to wash the girl's head, *piki* and on top of it *chaköbiki*, sweet corn meal, which is to be drunk in water.

Then the boy's uncles (*taamatö*) and the boy's father's brothers (*namatö*) [i. e. clansmen] bring in cotton to spin and weave for the girl. The girl's mother who is in the boy's house refills the baskets holding the cotton with

[11] At Oraibi the girl friends of the bride bring in trays of corn meal. The following morning the trays are returned filled with ears of corn by the groom's mother. ("Oraibi Marriage Customs," p. 241).

[12] On Third Mesa at Oraibi the groom's head is also washed at this time, by his mother-in-law. The bodies of the couple are also bathed. The heads of bride and groom are first washed in separate bowls, then in the same bowl, a symbolic act of union, according to Voth, which has lapsed in the case of a bridegroom who has had his hair cut short at school. (Voth, H. R. "Hopi Marriage Rites on the Wedding Morning," pp. 147-9. *Brief Miscellaneous Hopi Papers.* Field Mus. Nat. Hist. Pub. 157. Anthrop. Ser: Vol. XI, No. 2. 1912). At this headwashing rite at Oraibi wrangling by the women (see above and pp. 264-265) is said to occur, the visiting women trying to displace the bride. ("Oraibi Marriage Customs," p. 242).

[13] At Oraibi the girl's hair is taken down from the wheels or whorls worn by virgins by her own mother before mother and daughter take their first gift of meal to the boy's house ("Oraibi Marriage Customs," p. 240). The two rolls of the married woman's hair are wrapped with brown yarn stiffened with grease, so that the hair slips in and out of the wrapping or rather casing.

corn meal, in return for the cotton. The cotton is divided into four piles, the father of the boy is to make one *oba* (white blanket with red and black border), the boy's uncle, an *oba* and an *atõ*, (larger white blanket, embroidered), and the boy's father's brother, a belt (*wõkukwewa*). [They may also make a dress of black wool]. They take the cotton into the kiva, to spin[14] and weave They don't know how long it will take—several days, sometimes a month, sometimes less. (For Butterfly they were spinning three days, and weaving three days). During this time the girl is grinding or making *piki* in the boy's house, where her clanswomen come to help her. This is for the men at work in the kiva to eat. They take the *piki* to them every afternoon, and sweet corn meal in water. Besides, at this time, the boy's clanspeople come to the boy's house to eat. Whatever corn meal or *piki* is left over is given to the guests to carry away with them, [as is usual in Pueblo Indian circles when a meal is thought of as pay in kind.]

Through with weaving, they make the moccasins, perhaps the boy's father makes them, perhaps his uncle. The night of the day they finish making the moccasins, they take the girl back to her house, first dressing her up in her new things, and the boy follows her. For all of them, the mother of the girl has a meal ready. Earlier in the day the boy's mother has carried the girl's mother a basket of corn. Before the boy leaves his house, his people talk to him, telling him not to be lazy and to be good to everybody in his wife's house—"that is why he is getting married."

Early the next morning [after the night return to the girl's house] the clanswomen of the girl come in to wash the boy's head, just as the girl's head has been washed. Three days later the boy has to get wood. On the fourth day the girl's clanswomen come in to make *piki* all day. That evening they take the *piki* to the boy's house. The following evening those *piki* makers return to the girl's house to which the boy's mother brings some *piki* and meat for them to eat. That is the end of it. . . .

If the girl is married in the fall,[15] the following fall [i. e. a year later] they begin to grind corn again. They put the meal into twelve baskets[16] to take to the boy's house to pay for the wedding outfit."

"When is the first time they sleep together?" I asked. "The night of the morning they wash the girl's head. I forgot that." He forgot that, because, I presume, it was the ceremonial that was of significance, not the personal relationship. "I forgot that"—what more telling comment on wedding ceremonial—anywhere?

On my last visit to First Mesa I had the good luck to witness a wedding attack, the kind of mock or ceremonial attack referred to in the foregoing narrative, by the groom's father's kinswomen on his own kinswomen. High pitched voices were heard out of doors near

[14] Voth got the impression at Oraibi that any townsman might join in the spinning. ("Oraibi Marriage Customs," pp. 243-244).

[15] Fall or winter is the usual season for weddings (Oraibi Marriage Customs," p. 240). None would marry in *Kyamuye*, the dangerous moon, i. e. our December.

[16] The flat gayly colored baskets got in trade from Second Mesa. . . . At the time of my November visit, a year after Butterfly's wedding, her family had acumulated only eight baskets and when I left they had but seven, as they gave me one.

by, about four o'clock of an afternoon, and I was called out to see the sport of the "women's fight" and join in the laughter of the neighbors standing about. There were but two women on either side, to throw water and any refuse they could pick up in the street. One woman had already had her face smeared with mud when I arrived on the scene, and all were drenched. The attackers would vociferate in shrill tones against the closed door of the house of the groom's mother—they were charging the bride with being lazy, unable to cook or to work—and then one of the women would burst out from inside to throw water and to talk back, to say that the bride *could* work, *was* industrious, etc. (No other insults appear to be indulged in on these occasions, there are, for example, no sex jeers.) But for the amused and non-interfering bystanders, two dozen or so, the row seemed thoroughly realistic. It was vigorous, though brief, lasting less than an hour.

The bride of this occasion was the sister of the town chief, the *gigyawuxti* or one of the chiefs of the houses, corresponding to the woman member of the *kyakweamosi* (chiefs of the houses) of Zuñi. She had been married before and separated, as had the groom. During the ceremonial row she remained, not in the maternal house of the groom, but in her own house at Walpi. That morning she had been married by government license in the schoolhouse below the Mesa.[17] Marriage by license in the morning and in the afternoon a wedding assault, what uncritical theorizers would once have called a "rape symbol"! New custom and old, side by side, as is ever the way in Pueblo Indian life

Although the old custom, the assault, is not a symbol of rape, since the grievance is on the part of the groom's people, his father's people against his mother's people, it is, nevertheless, we may fairly assume, give certain other data,[18] a symbol or survival of an earlier custom, that of cross-cousin marriage, where the favored or acceptable marriage was with the father's sister's daughter or clanswoman.

[17] Hopi converts, "Christians" as they are called, are married in the church; but the unconverted are likewise required by government to be married, in the schoolhouse.

[18] See Freire-Marecco, B. "Tewa Kinship Terms from the Pueblo of Hano, Arizona," *American Anthropologist*, XVI, 286, 1914. For his paternal aunt to call a boy "our bridegroom" is also Hopi practice or joke. Another Hopi joke is that were a man to marry his father's sister's daughter (clanswoman), a certain lizard called *manaña* would dart at him. Oppositely, at Laguna, children are told that if they are shy of calling certain connections by the cross-cousin terms of relationship, which is "just like saying husband or wife," the lizard will dart. The cross-cousin terms of relationship in several Pueblo tribes point to some time cross-cousin marriage. In the Hopi *hoinawee*, a war dance, the girl dancers appoint the men dancers, appointing from their mother's brother's sons. As sexual license once characterized war dances, in this choice of dance partners may be seen another hint of cross-cousin mating.

HARMONIZING HORMONES

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THE mechanism of coordination within the animal body is one of the most subtle of all the organ systems of the higher animals, as it is one of the subtlest properties of the microscopic body of the protozoa. What it is in the single cell of the Paramecium, for example, that enables all the cilia covering its body to beat harmoniously in order to propel the organism either forward or backward is quite unknown. Our ignorance we cover by saying it is a property of the living substance to adapt itself to its environment and hence to advance or retreat according to the stimuli it receives. I have no desire at this time to inquire into this question of adaptation, interesting though it be, nor have I any desire to become involved in the discussion of a possible "vital principle" at work to keep the organism behaving as a perfectly unified body capable of maintaining itself in a changing environment.

The problem I would consider very briefly has to do with the visible or physical coordinators that can be demonstrated in the laboratory and that do not lead us at once into the realm of metaphysics.

There are three well defined coordinating systems in the higher animals. The simplest is made up of the connective tissues which hold the different parts of the body in proper spatial relations to each other, which exert pressures and tensions on different parts and prevent the mechanical interference of one part with another. Ligaments and bones by their special forms and attachments prevent us from wringing our own necks. In addition to the connective tissues, which are mechanical coordinators, the muscles may also be mentioned. The muscles of the neck must be strong enough to keep the head balanced and the tongue, though it may be "hung in the middle" in some of us must not be too large to fit comfortably within the mouth cavity. The second and far and away the most complex system of coordination is the nervous system which has evolved in the course of the history of living things to an elaborateness beyond that of any other. Coordination by means of the nervous system is brought about by the peculiarly specialized property of nerve cells of transmitting certain changes along their length so that the modification of one part of the body by a stimulus is transmitted to other distant parts and throws them into activity. The exact nature of these nerve impulses is still quite problematical but there has recently come to light evidence of their chemical nature since carbon

dioxide is liberated more abundantly by a nerve along which impulses are passing than by one not active. The third form of coordinator in the body is the circulatory system by means of which materials are transported through the medium of the blood and lymph. By virtue of the rapid movement of the blood stream, all parts are furnished with a uniform nutriment and oxygen supply and washed free of accumulated wastes, and at the same time bathed with special chemical substances which modify the action of different parts of the body.

It is only very recently that the full significance of this last class of coordinators has been realized and it is to this system that I would call your attention specially. Within the past few years the energies of a great number of physiologists have been directed to certain specialized organs having the structure of glands but not communicating with any free surface by means of ducts. These organs secrete internally, directly into the blood stream from which they have derived the raw materials from which the hormone is secreted. The effects on neighboring organs of the products of other organs has been studied with great earnestness for some years, but our knowledge is still in its infancy. From the medical point of view there have been some remarkable advances made in this field. As Sir William Osler said recently, medicine has made no more brilliant advance than in the cure of certain diseases of these ductless glands.

One of the most important hormones which is produced by every living cell in the body is carbon dioxide. This is the normal product of cellular activity and affords a kind of measure of the vitality of a part. Resting, inactive cells produce comparatively little; actively contracting muscles or secreting glands produce large quantities. This waste matter, the product of the metabolism of the cells, is poured into the blood to be eliminated finally in the lungs. But before it is finally got rid of, it stimulates the respiratory center of the brain which activates the respiratory muscles. The more active the respiratory center, the more rapid and deep is the respiration. There is a most perfect coordination between the respiratory activity and the muscular activity of the body generally so that the quantity of carbon dioxide in the blood is maintained practically constant. Although breathing is under the control of the will within limits, we ordinarily respire involuntarily and unconsciously, and we take a breath only when the blood reaching the respiratory center of the brain contains an excess of carbon dioxide and stimulates it to greater activity; a fact which may be proved by any one most readily. Sitting quietly with watch in hand, the experimenter breathes rapidly and moderately deeply for from one half to one minute thus ventilating the lungs thoroughly. Then without trying to hold the breath he will note how long an interval passes before the slightest impulse to breathe is felt. In this case, by the thorough ven-

tilation of the lungs more than the normal quantity of carbon dioxide passes out of the blood and is exhaled so that the blood reaching the respiratory center is abnormally poor in CO_2. The interval, until the impulse to breathe again is felt, represents the time it takes for carbon dioxide to accumulate in the blood to the normal amount. Conversely, the inhalation of carbon dioxide leads to more rapid and forced breathing because of the over-stimulation of the respiratory center. Before the young mammalian is born it does not breathe air through the lungs; in fact, its lungs do not begin to function until the infant is separated from the maternal blood circulation and the carbon dioxide produced by the activity of its cells has accumulated sufficiently in the blood to throw the respiratory center into activity and in consequence the muscles by means of which the air is changed in the lungs. This, of course, is simply a matter of seconds.

That it is the composition of the blood which determines the activity of the respiratory muscles may also be demonstrated in another way. The lungs of birds are so connected with air spaces which extend through the bones that it is possible to pass a continuous stream of fresh air through them by connecting the cut end of one of the larger bones with a suitable pump. Under the circumstances, the bird makes not the slightest respiratory movement for an indefinite time since its blood is maintained in a perfectly normal arterial condition, with an abundance of oxygen in it and unable to stimulate the respiratory center.

Another most clearly proved chemical harmonizer, which makes the pancreas secrete at the moment its secretion is needed, is the substance secretin which is formed in the intestine by the stimulation of the intestinal wall by an acid. This substance is carried to the pancreas in the circulation and causes that organ to secrete pancreatic juice, the most important digestive juice. The stimulation of the pancreas by some material transported thither rather than by nervous stimulus has been proven in several ways. All the nerves connected with an isolated loop of intestine are cut, so that no impulses can pass from the stimulated part of the intestine, but the blood vessels are left intact. An acid, like the acid of the gastric juice, is introduced into this isolated part of the intestine and the flow of pancreatic juice is noted. The increase of the flow of pancreatic juice is quite as great as when the nerves are not cut. Again, it has been found that the blood leaving the intestine which has been stimulated by an acid has the power of stimulating the flow of pancreatic juice in a second animal into whose blood vessels this blood is injected. It has been demonstrated also that acid in the blood alone has no such effect on the flow of pancreatic juice. Here we have a clear example of harmonious, purposeful action; namely, the secretion of pancreatic juice at the time that the contents of the stomach

pass into the intestine, effected through a definite chemical substance manufactured in the intestine under the influence of an acid and transported to the pancreas.

Some very interesting cases of accurate coordination through chemical means have been noted in the development of the embryo from the egg. Let me illustrate with some experiments on the development of the eye of the tadpole. You may recall that the fine coordination displayed by the development of the eye was a stumbling block to Darwin in the way of the general acceptance of the theory of natural selection. The experimenter, however, has shown that to some extent this beautiful and complex coordination of parts is accomplished by chemical substances produced by certain organs. Before explaining the experiments, it will be necessary to describe very briefly the embryology of the eye. At a very early age before the body form of the embryo has been established and before many organs have been laid down, the brain broadens out in the form of a small conical projection on each side. The apex of this cone finally reaches the level of the skin. This swelling is known as the optic vesicle and from it is derived the portion of the eye which is sensitive to light, the retina. The bit of skin in contact with the apex of the optic vesicle sinks down beneath the surface like a little cup or pit, pushing the optic vesicle down with it, just as one might push in one side of a rubber ball with the thumb. The margins of this depression finally close together forming a hollow ball which becomes separated from the skin. This later becomes the lens of the eye. These are facts which could be demonstrated to you in a half hour in the laboratory. The lens of the eye, of course, is very different from the skin and if we did not know its embryological history we would hardly guess that it was derived from the skin. The embryologist used to think that the bit of skin which came to lie directly over the optic vesicle was unlike the rest of the skin, being endowed with special powers of forming the crystalline lens of the eye, and the mystery was, how it chanced that these lens-potentialities were accumulated at exactly the right spot and that there did not occur at times stray lenses scattered about on other parts of the body. The experimentalist, however, who has done so much to destroy illusions and push further back the limits of the mysterious, has shown that the formation of the lens depends entirely upon the contact of the optic vesicle and that any part of the skin under the influence of this structure will develop into a lens. Under the dissecting microscope with very fine needles it is possible to operate on the young tadpole before the eye is formed and to transplant the optic vesicle to some other part of the body. The results of this very drastic treatment are that any part of the skin which overlies the transplanted optic vesicle will form a lens. Any embryonic skin of the right age apparently has the power

of developing into a lens under the proper stimulus. In fact the experimenter has gone so far as to graft two tadpoles of different species in such a way that the optic vesicle of one comes to lie directly beneath the skin of the abdomen of the other. But even here the skin of the abdomen of the strange tadpole developed a lens in a perfectly orthodox fashion.

Darwin today would not be so mystified over the question of how the different layers of tissue of different degrees of transparency and refraction chanced to occur in the right relations to each other to form a complex purposeful organ like the eye. The difficulty to-day is to explain how the skin of the embryo is endowed with such wonderful powers and how the optic vesicle is able to call forth such a complex response.

The phenomenon of internal secretion, that is, the discharge of substances manufactured by an organ directly into the blood passing through the organ and not to a free surface, was discovered by the great French physiologist, Claude Bernard, in 1876, when he demonstrated that the liver manufactures sugar and pours it constantly into the blood passing through that organ. Besides these organs which only incidentally to other functions secrete into the blood, like the liver, the pancreas, the sex glands and the developing fetus in the mammal, there are certain organs specialized for this purpose alone. These are called ductless glands, because they have no outlet to a surface, or endocrine organs, that is, organs secreting to the inside. The most important of these are the pituitary body, situated on the under side of the brain next to the roof of the pharynx and tucked into a little pocket on the floor of the skull; the pineal body, on the upper side of the brain but buried deep in the crease between the two halves of the cerebrum; the thyroid gland situated on the front of the throat just below the "Adam's apple" and enlarged in goitre; the thymus gland situated in front of the heart, from which the true "neck sweetbreads" are taken; and the adrenal bodies situated just above the kidneys.

The ductless glands just enumerated seem to have the most marked effect upon growth, development, and nutrition. Some of them, especially the adrenal body, also have a marked effect upon the blood pressure.

The thyroid gland influences powerfully the growth of the body and the rate at which the mature state is reached.

A few years ago one of our American experimenters showed that the growth of the tadpole may be stopped almost immediately by feeding thyroid gland. At the same time that the increase in size ceases, the transformation of the tadpole into a frog goes on with increased speed. Tadpoles were obtained which had the fore legs in fifteen days from the time that they issued from the egg while ordinarily they ap-

pear only after about four months. The action of the thyroid gland on the human subject seems to be somewhat different from that just described although its action affects development. The distressing disease, cretinism, characterized by the squat stature and low mentality, with puffy skin and bleary eyes, is the result of insufficient activity of the thyroid which may be made good by feeding thyroid glands from oxen or sheep. Thyroid feeding is sometimes employed to reduce obesity, as under its stimulus more rapid oxidation of the tissues takes place. Thyroid fed to immature rats retards growth. Rats fed thyroid gland do not gain weight as rapidly as normal ones. To one-half of a litter kept under conditions as nearly like the other half as possible were fed small quantities of thyroid. In three or four days the thyroid individuals gained only 4.2 gms. on the average as compared with 10.1 gms. for those not specially fed.

Another organ which has a very marked effect upon growth is the pituitary body, a small structure which is attached to the under side of the brain and which originates in the embryo from the roof of the mouth. When this gland secretes more than the normal amount in childhood before growth is completed, gigantism results and the child continues its growth beyond the normal and becomes a giant. The overactivity of the same gland later in life when normal growth is complete leads to a disease known as acromegaly in which the extremities of the body alone grow abnormally. Conversely, if the pituitary body is removed or if it is not sufficiently active on account of disease, there follows a condition known as infantilism, characterized by the development of much fat beneath the skin and more or less atrophy of the sexual organs.

Regarding the function of the thymus we are especially in the dark. As is well known it degenerates before the adult condition is attained and it may be removed from young animals apparently without causing any modification in the rate of growth or any special symptoms of any kind. The feeding of thymus gland to tadpoles has been found, however, to have a marked effect upon growth, prolonging the period of growth and inhibiting the metamorphosis of the tadpole.

The action of the adrenal bodies has already been alluded to. The removal of the organs is followed by death in about 36 hours in the mammals ordinarily used for experimental purposes like dogs, cats, rabbits, and the like. When the adrenals are diseased, a number of definite symptoms known as Addison's disease appear; the skin assumes a coppery color, there is great muscular weakness and lowering of the temperature of the body. The application of the extract of the gland—adrenalin—to a bleeding or inflamed part is followed at once by a constriction of the capillary blood vessels and a blanching of the part. This property, of course, makes the extract of great value to the sur-

geon in operations in which there is profuse bleeding from many tiny blood vessels, like many operations on the nose. So powerful is the hormone of the adrenal body that one part of adrenalin in one hundred million of Ringer's solution produces marked effect on the contraction of involuntary muscle.

The pineal body, which Descartes thought was the seat of the soul of man, has a most obscure function which cannot at present be clearly defined. The removal of the organ is very difficult without serious injury in the operation. When it is successfully removed without injury to the animal there has been found to be in some cases a precocious development of the sexual organs but in other experiments the effects have been negative.

The ductless glands seem to be more or less closely related to each other in function so that the removal of one may be accompanied by changes in others, but it is apparent that there is much still to be learned regarding the exact working of these very subtle organs. The fact, however, that the precise functions of some of these organs have not been exactly determined does not mean that they have little effect upon the organism as a whole. What has just been said regarding the pituitary, suprarenals, and thyroids shows that the contrary is the fact.

Considering the organs which only incidentally secrete internally, the pancreas exhibits a very interesting harmonizing action. The function of the pancreas is not only the secretion of a digestive juice which performs the great bulk of the digestion of food in the intestine, but also the secretion into the blood of something which enables the sugar absorbed from the intestine to be stored in the liver until needed in the active organs of the body. If the pancreas is removed entirely, diabetes appears at once due to the failure of the liver to remove the sugar from the blood. In order to determine that this condition is not due simply to the elimination of the pancreatic juice from the alimentary canal, the experiment has been made of simply tying off tightly the duct leading from the pancreas to the intestine, but not interfering with the circulation of the blood through the organ, and also of grafting the pancreas which has been cut out, on some other part of the body so that blood will pass through it. In both these experiments diabetes does not appear and we must conclude that the pancreas secretes into the blood a substance which enables the liver to store up grape sugar.

The effects of the reproductive organs upon the body as a whole have been known in a general way from time immemorial. Especially in the male sex have the reproductive organs been removed for economic or social reasons. Emasculation in the human subject when performed in early youth prevents those changes from taking place which normally occur at puberty, such as growth of hair on various parts of the body, the growth of the larynx with the consequent lowering of the pitch of

the voice, and the growth of the chest. It has been said also that in oxen and horses the removal of the male sexual organs at an early age causes the haunch bones to change to the female type. It has been known for years that if the very young male deer is castrated, the antlers never appear and if the operation is performed when the antlers have already begun to develop, they fail to reach their normal size and remain covered with the velvet, like young antlers. In the adult deer castration causes the antlers to be shed precociously and they are replaced, if at all, by imperfect antlers which are never renewed. Thus we see that the complex changes involved in the development of the antlers are dependent upon the presence of something supplied by the sex glands of the male.

The female sex organs are no less potent in determining the course of development. One experimenter removed the testes of a guinea pig and a rat and replaced them with ovaries from a female. The presence of the ovaries in the body of the emasculated male led to a remarkable development of the mammary glands and a change in the proportions of the skeleton to more nearly those of the female. Another important change is that the size of the feminized males is less than that of the normal castrated males, showing that there is something produced by the ovary which prevents the normal growth of the male. These experiments are not numerous but they indicate something of the power of the sexual organs to determine by their internal secretions the growth and relative size of parts of the body.

Equally marked effects have been noted in the case of birds. The desirable effects of removing the male organs have been known for many years and capons have been highly esteemed as delicacies. It is well known, of course, that the removal of the male organs in poultry leads to increased size and deposition of fat. Notwithstanding, the male plumage with all the secondary sexual characters appear as in normal birds. During the past few years the experiment of removing completely the ovaries from a female bird has been successful. In this case the ovaries were removed from a very young Mallard duck, in which the plumage of the male and female are very different. It was found that the plumage of the spayed female became similar to that of the male.

The developing fetus within the uterus of the female exercises an important effect upon the development of the milk glands so that the latter are able to supply an abundant nourishment for the young which are to be born shortly. This effect is produced by the discharge of some substance into the blood stream of the mother through the placenta. This has been demonstrated with rabbits by injecting into the blood vessels of a virgin rabbit, in which the milk glands are practically invisible, the extract of a fetus taken from a pregnant female.

The injection is followed by a rapid growth of the glands. That this effect is produced directly upon the milk glands and not indirectly through the action of the uterus and ovaries has been shown by making the injection after the removal of those organs. The effect upon the milk glands is just as marked as when ovaries and uterus are present. A further confirmation of the harmonizing of the activity of the mammary glands and the needs of the body through hormones is afforded by the famous case of the Blazek sisters who were joined like the Siamese twins with blood vessels united but with entirely separate nervous systems. In spite of the absence of nervous connections between the two, pregnancy in the one produced a normal growth of the mammary glands of the other, and with the birth of the child the secretion of milk by the glands of the two sisters occurred. A third method of demonstrating the chemical control of the mammary glands is by severing the spinal cord at the level from which the nerves going to the glands are given off, so that the nervous connections between the two ends of the mammary glands in such an animal as the dog whose glands extend along the entire length of the abdomen, are severed. In spite of this separation, however, secretion occurs simultaneously in all the glands.

Our knowledge of the presence and action of hormones in the blood is in its infancy. There can be little doubt that further investigations will prove that many more are working in the body than we dream of now and that their effects may be found to be of far more importance. The endocrine organs can not be supposed to allow of the complex development which the nervous system has experienced in the animal kingdom nor can it ever have the same far-reaching effects, but enough perhaps has been presented to show how the integration of the body as a whole is brought about by non-living products of cells circulating in the blood. In conclusion, however, we can hardly say that the physiologist, studying the chemical harmonizers of the body, has solved the problem of individuality, or that the conception of the animal body has been rendered more simple as a result of these discoveries. The explanation of the timely appearance of these harmonizers and the mechanism of the complex reactions to them is quite as difficult and perplexing as that of the harmonies themselves. The knowledge of these chemical bodies is an aid to us in pushing back further in the life cycle those forces or mechanical devices which are capable of producing the integrated living body, and the harmonizers of the body afford a mechanical explanation of many phenomena which in the past required a mystical or vitalistic explanation. The chemical harmonizers in their action and the response of the body to them are quite as baffling as the fact of harmonious action itself, so that pushing back the mystery only deepens it.

GRAZING PRACTICE ON THE NATIONAL FORESTS AND ITS EFFECT ON NATURAL CONDITIONS*

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THE statutory purposes of the national forests are to insure a perpetual supply of timber, to preserve the forest cover which regulates the flow of streams, and to provide for the use of all resources which the forests contain, in the ways which will make them of the greatest permanent good to the entire nation.[1]

Grazing on the national forests is regulated with the object of using the forage resources to the fullest extent consistent with the protection, development and use of the other resources. Since the national forests were established primarily for the protection and development of the forest resources and the protection of the watersheds, great care is taken to harmonize grazing with these primary purposes. The importance of adjusting grazing so as to secure the perpetuation of the range resources and yet not to interfere with the requirements of the other resources is emphasized in the administration of the national forests.[2] If the fundamental principles of range management, such as the proper division of the range among different classes of stock, the establishment of correct periods of grazing, stocking the range to actual carrying capacity, and securing proper management of the stock are followed in practice, actual damage to the forests will be limited to unusual cases where a combination of factors makes special treatment necessary to insure the proper protection of the forest resources and the watersheds. The forest officers in charge of the administration of grazing fully appreciate that much remains to be done in developing range management, especially in connection with the determination of the proper grazing season and methods of handling stock on the national forest ranges.

Through a series of investigations and experiments extending over

* Prepared for the Committee on the Preservation of Natural Conditions of the Ecological Society of America.

[1] U. S. Forest Service. The National Forest Manual; Regulations and Instructions. 1914.

The Use Book; A Manual of Information about the National Forests. 1918.

[2] Jardine, James T. and Anderson, Mark. Range Management on the National Forests. U. S. Dept. of Agri. Bull. 790. 1919.

FIG. 1. SHEET AND GULLEY EROSION ON AN OVERGRAZED RANGE IN NORTHWESTERN NEVADA. Snow lies on the Lare portion in the background until early summer and the cattle follow the receding snow, eating all of the succulent vegetation before it has become established. The Forest Service has closed this watershed together with three others aggregating 20,000 acres to grazing by all classes of livestock, for a period of at least five years for the purpose of revegetating the range with palatable forage plants and of regenerating the stands of aspen on the watersheds.

FIG. 2. ASPEN SPROUTS AND A FAIR STAND OF FORAGE ON THE AREA, A PORTION OF WHICH IS SHOWN IN FIG. 1, AFTER IT HAD BEEN CLOSED TO GRAZING FOR TWO YEARS. After the aspen reproduction has become established and is out of reach of the grazing of livestock, the areas will be opened to regulated grazing and probably other areas closed for a like period. This practice will be continued until the entire Forest has been revegetated to forage plants and regenerated to aspen reproduction.

a period of years, a number of important principles of range management and management of livestock have been developed for harmonizing grazing use with the regeneration and growth of forests.[3]

A proper understanding of the forest cover in relation to the regulation of stream flow and erosion is important in range management, since "cover" in the sense used includes the tree cover, the herbaceous and shrubby cover, and the surface soil with its comparatively rich admixture of organic matter.[4] Over-grazing frequently results in packing the soil, decreases its power of absorbing and holding precipitation, and causes the partial or complete destruction of the ground cover, a condition almost invariably associated with erosion and the reversion of the native vegetation to a lower successional stage.[5] In this case the reestablishment of the more permanent type of vegetation is prevented until, with the return of the original fertility of the soil, the sub-climax species again appear.

The grazing of livestock may either retard or promote the development of the vegetative cover and cause either retrogression or progression of the types, depending chiefly upon the closeness with which the herbage is grazed annually and the time of cropping.[6] Continuous premature and too close grazing not only favor degeneration of the cover and ultimately the destruction of the vegetation, but also tend to impair the fertility of the soil through erosion. On the other hand, deferred-and-rotation grazing, that is, grazing the depleted range only after seed maturity and later applying this practice in rotation to all the other parts of the range favors progressive succession.[7] The effects of grazing upon plant succession depend not only on the character and intensity of grazing, but also upon the type of vegetation. However, it may be said that properly regulated grazing shows a tendency to hold

[3] Cf.

Sampson, Arthur W. and Dayton, William A. Relation of Grazing to Timber Reproduction. U. S. Forest Service Review of Forest Service Investigations, Vol. 2, pp. 18-24, 1913.

Hill, Robert R. Effects of Grazing Upon Western Yellow Pine Reproduction in the National Forests of Arizona and New Mexico. U. S. Dept. of Agri. Bull. 580, 1917.

Sparhawk, W. N. Effects of Grazing Upon Western Yellow Pine Reproduction in Central Idaho. U. S. Dept. of Agri. Bull. 738, 1918.

Sampson, Arthur W. Effect of Grazing Upon Aspen Reproduction. U. S. Dept. of Agri. Bull. 741, 1919.

[4] Reynolds, Robert V. R. Grazing and Floods: A Study of Conditions in the Manti National Forest. U. S. Forest Service Bull. 91, 1911.

[5] Sampson, Arthur W., and Weyl, Leon H. Range Preservation and its Relation to Erosion Control on Western Grazing Grounds. U. S. Dept. of Agri. Bull. 675, 1918.

[6] Sampson, Arthur W. Plant Succession in Relation to Range Management. U. S. Dept. of Agri. Bull. 791, 1919.

FIG. 3. A BADLY OVERGRAZED AREA ON A POORLY MANAGED CATTLE RANGE ADJACENT TO THAT SHOWN IN FIG. 2 IN NEED OF REMEDIAL MEASURES. The complete absence of aspen reproduction and the dearth of palatable forage plants is evidenced by the barren appearance of the surface of the ground. Erosion is also evident.

FIG. 4. AN OLD BURN IN A LODGEPOLE PINE FOREST IN CENTRAL IDAHO WHICH IS ADEQUATELY RESTOCKING WITH NATURAL REPRODUCTION. The forage is being properly utilized as a result of regulated grazing, so that no injury is resulting to either the forest tree seedlings or to the forage plants themselves.

the vegetative succession in one of the sub-climax, or occasionally climax stages of the herbaceous and shrubby vegetation, but should offer little or no interference with the climax forest type, since grazing is very frequently excluded from forest areas being regenerated.

The value of regulated grazing as a means of fire protection is recognized in the utilization of the annual growth of grass, which, if not utilized, becomes dry and inflammable, and a real cause of forest fires.[8] It is thus seen that grazing in itself is beneficial as a control of fires. In addition to this, the extensive work in forest fire prevention and suppression is a very important factor in promoting and maintaining climax types of vegetation.

With the development of the livestock industry in the West, came the economic necessity of controlling predatory animals. The decrease in their number, especially of the coyotes, probably resulted in an increase in the number of rodents, many of which are active range destroyers. These in turn have had to be controlled. With the decrease in the number of predatory animals there should be an increase in the number of game animals; but this has been largely, if not wholly, offset by the increased number killed by hunters within recent years.

The national forest policy provides that the protection and development of the wild life of the forest must go hand in hand with the development and management of the range resources for use by domestic stock. Before opening up new range to domestic stock the use or probable use of the area by game is carefully considered.

Suitable camping grounds are provided on the national forests and are given sufficient protection from grazing to preserve their natural attractiveness for the recreational use of campers and tourists.

The conserving of the national parks in an unmodified condition in the interests of natural history and research and the desirability of maintaining the original balance between the plant and animal life has already been emphasized.[9] The management of areas for game and fish production will doubtless cause disturbances and readjustments in

[7] Sampson, Arthur W. Range Improvement by Deferred and Rotation Grazing. U. S. Dept. of Agri. Bull. 34, 1913.

Sampson, Arthur W. Natural Revegetation of Range Lands Based upon Growth Requirements and Life History of the Vegetation. Journal of Agricultural Research, Vol. 3, No. 2, pages 93 to 148, 1914.

Jardine, James T. Improvement and Management of Native Pastures in the West. U. S. Dept. of Agri. Yearbook Separate 678, 1915.

[8] Graves, Henry S. Grazing and Fires in National Forests. American Forestry 17:435. 1911.

Hatton, John H. Livestock Grazing as a Factor in Fire Protection on the National Forests. U. S. Dept. of Agri. Circ. 134, 1920.

[9] Grinnell, Joseph and Storer, Tracy I. Animal Life as an Asset of National Parks. Science, N. S. 44:375-380, 1916.

FIG. 5. AN OPEN STAND OF LODGEPOLE PINE IN CENTRAL IDAHO ON AN AREA WHICH IS BEING GRAZED TOO HEAVILY BY LIVESTOCK. Note the absence of forage plants and the flattened, bushy shape of the lodgepole pine seedlings, which is not characteristic of this species, due to being browsed by the stock. The injury was eliminated, and the range is being restored through properly regulated grazing based on the scientific principles of range management as worked out by the grazing specialists of the Forest Service.

FIG. 6. YOUNG DEER ON GARDINER RIVER, MONTANA. The concentration of game animals on winter ranges may result in over-grazing and even eliminate certain desirable forage plants from the range.

the ecological balance between the plant and animal life, both terrestrial and aquatic. The introduction of exotic species may become a dangerous factor in disturbing the original balance, even to the extent of assuming economic proportions. The uncontrolled increase of game animals on game preserves may produce conditions very similar to those resulting from the grazing of domestic stock. However, in most cases the number of game animals on any range should be limited to the number which the range will carry through the winter.

FIG. 7. AREA IN BIG COTTONWOOD CANYON ON THE WASATCH NATIONAL FOREST IN CENTRAL UTAH WHICH IS CLOSED TO LIVESTOCK GRAZING BECAUSE IT IS ONE OF THE MAIN SOURCES OF SALT LAKE CITY'S MUNICIPAL WATER SUPPLY AND ALSO ON ACCOUNT OF ITS IMPORTANCE FOR RECREATIONAL USE.

In rendering the secondary uses of the national forests compatible with the primary uses and in harmonizing the secondary uses, it frequently becomes necessary to close areas to grazing as, for example, watersheds which comprise important sources of municipal water supply; recreational areas and those of unusual scenic attractiveness, such as the national monuments; areas on which the range is needed for important game animals; and forest areas in the course of regeneration. From the list of areas on which natural conditions are now being preserved, [10] it is seen that the forest areas are of considerable size.

[10] Compiled by the Committee on Preservation of Natural Conditions of the Ecological Society of America and to be published in the near future.

THE PROGRESS OF SCIENCE

HELMHOLTZ AND VIRCHOW

One hundred years ago were born in Prussia Hermann Helmholtz and Rudolf Virchow, the former in Potsdam on August 31, 1821, the latter in an obscure village of Pomerania on October 13, 1821.

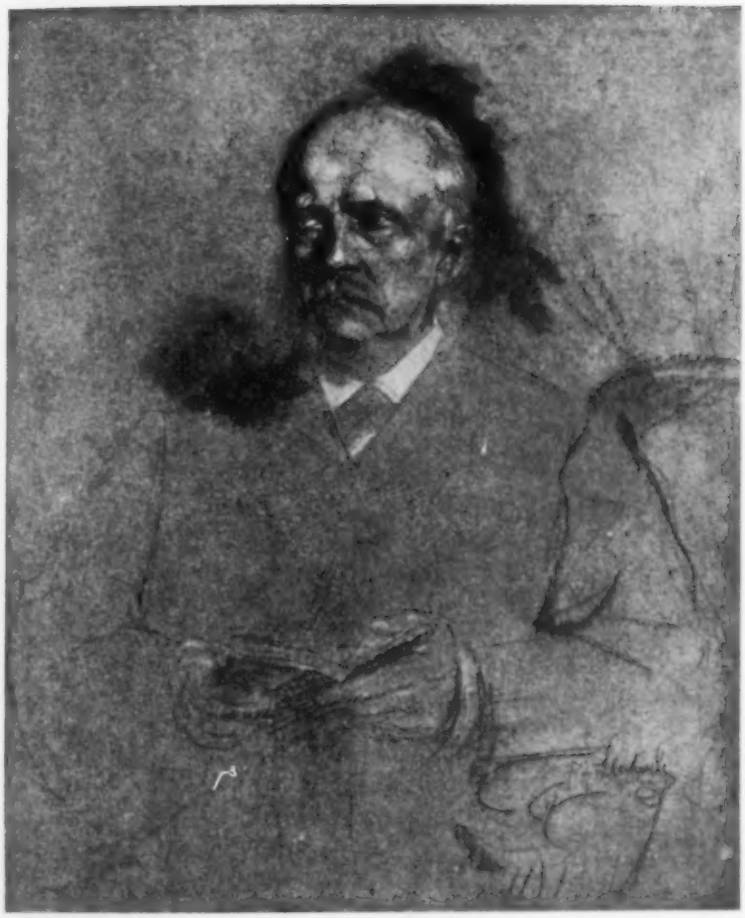
The University of Berlin was opened in 1810 after Prussia had lost by the peace treaty of Tilsit the University of Halle, which Napoleon included in his new kingdom of Westphalia. Germany, defeated in war, required to pay an immense indemnity, its army limited to 42,000, turned its energies to education and to science. Both Helmholtz and Virchow were students of medicine in Berlin, and later became professors in the university. Their genius was born with them, but the stimulus and the opportunity to apply it to the advancement of science must in large measure be attributed to the spirit of the university founded by Humboldt and his associates when the political fortunes of Prussia were at low ebb.

Helmholtz was the son of a gymnasium teacher, his mother, Caroline Penne, being a descendant of William Penn. After a childhood of ill health, he studied medicine and was for four years a military surgeon; for a year he was teacher in the Berlin Academy of Fine Arts, and afterwards from 1849 to 1855 professor of physiology at Königsberg. He was professor at Bonn for three years and was then professor of physiology at Heidelberg from 1858 to 1871, when he was transferred to Berlin as professor of physics. In 1888 he was made president of the Reichsanstalt, organized under his direction. All possible academic and national honors were conferred upon him.

A list of von Helmholtz's contributions to science would fill many pages. The essay on the conservation of energy was printed in 1847. Researches of great range and importance, including the invention of the ophthalmoscope, led to his two epoch-making books on physiological psychology—"Tonempfindungen" (1862) and "Physiologische Optik" (1867). Helmholtz always continued his work in physiological psychology, but his transfer from a chair of physiology to one of physics represented a change in his main interests. His great contributions to mathematical physics, especially electrodynamics, are of almost unparalleled importance.

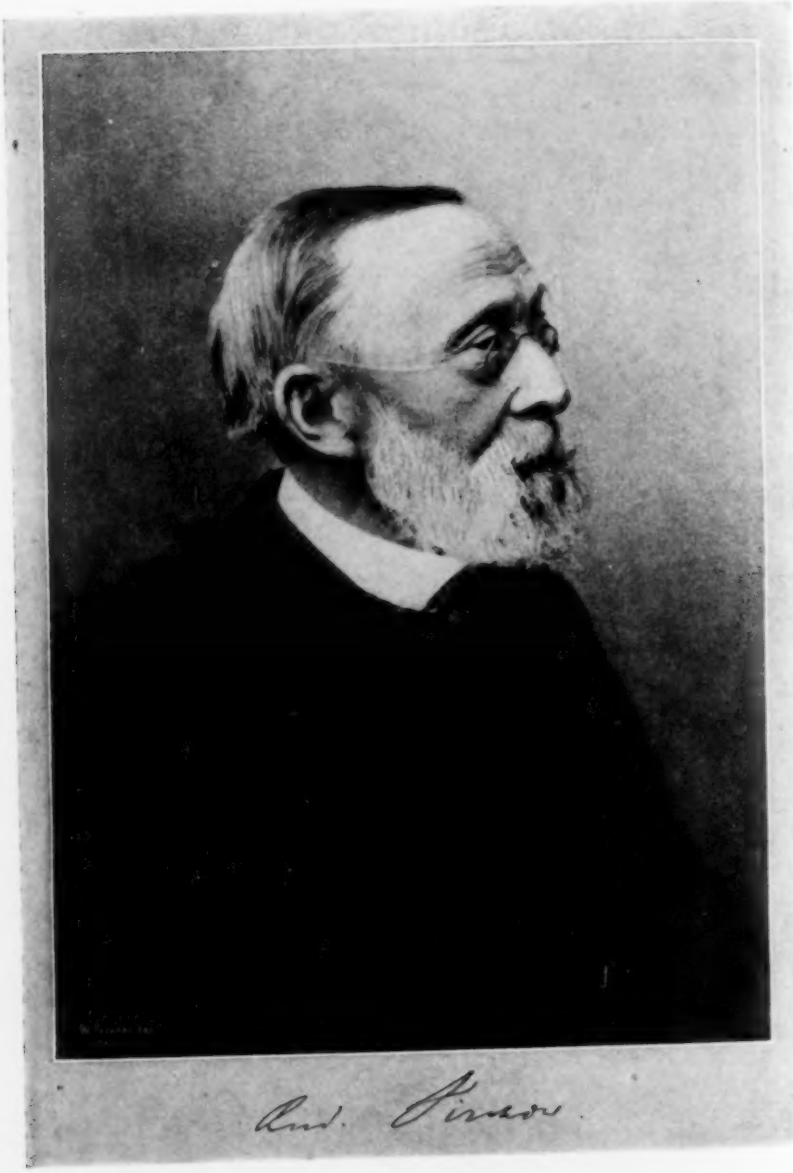
Virchow more than any other one man established the science of pathology and made it possible for medicine to become an applied science. Only second in importance to his contributions to pathology was his work in anthropology which covered all branches of the science. His scientific work was singularly complete. He made numerous and exact observations and experiments; he deduced from them wide-reaching theories; he conducted an important journal for more than fifty years; he wrote text-books, summaries of scientific advances and books popularizing science; he established a school to which students came from all parts of the world, while at the same time taking part in the education of the people; he founded a great museum and took a leading part in scientific societies; he applied science directly to human welfare.

It is almost incredible that among these multifarious scientific activities Virchow should have been one of the leading statesmen of his country. He was a member of the municipal council of Berlin for more than forty



From a drawing by Lembach (1894)

HERMANN VON HELMHOLTZ



And. Simon

years, and through him the hygienic conditions of the capital were revolutionized. He was from 1862 a member of the Prussian chamber and was for twenty-five years chairman of the committee on finance. He was leader of the radical party in the Reichstag. In his public career he opposed centralization, autocracy and war, and advocated all measures for the welfare of the people. He was at one time compelled to leave the University of Berlin owing to his political activity, but his personality and eminence were such that he was recalled to a professorship in 1856, and he was thereafter the preeminent representative of academic freedom.

THE INTERNATIONAL INSTITUTE OF AGRICULTURE

The president of the International Institute of Agriculture at Rome has transmitted to the Secretary of Agriculture, through the State Department, a copy of resolutions adopted in April, 1921, by the permanent committee of the institute, authorizing the conferring of the title "donating member" upon any person who makes a gift, donation, or contribution to the institute amounting in value to 10,000 Italian lire, which at normal rates of exchange is equivalent to about $2,000.

The International Institute of Agriculture was established as the direct result of the efforts of David Lubin, a successful merchant of California, with the active support of the King of Italy, who foresaw the advantages which would accrue to agriculture, commerce, and industry from an international clearinghouse for systematically collecting and disseminating official information supplied by the various governments of the world on agricultural production, consumption, movements, surpluses, deficits, and prices of agricultural products, transportation, plant and animal diseases and insect pests, rural credits and insurance, standard of living, wages and hours of labor on farms, cooperative organizations of farmers, legislation affecting agriculture, and similar information. The international treaty was drafted at Rome on June 7, 1905, and has since been ratified by more than 60 governments.

The institute survived the trying period of the World War and is now entering upon a period of expansion and increased usefulness. Its work benefits all peoples. In accordance with the recent action of the permanent committee, which is made up of delegates from the adhering governments and serves as a board of directors of the International Institute of Agriculture, citizens of the United States and other countries who are in sympathy with the purposes of the institute have an opportunity to contribute to its support and development and to receive permanent recognition therefor as "donating members" by having their names and nationality and the date of their donation inscribed on a marble tablet which will be placed in a conspicuous position in the halls or vestibule of the marble palace occupied by the institute, situated in a beautiful park on an elevation overlooking the Eternal City. Such donations can be made either through the Secretary of Agriculture, the Secretary of State, or the American delegate to the International Institute of Agriculture, Rome, Italy.

THE NATIONAL GEOGRAPHIC SOCIETY'S GIFTS OF BIG TREES

The trustees and officers of the National Geographic Society announce to members that the society has been continuing its efforts, begun in 1916, to preserve the Big Trees of Sequoia National Park. By a final purchase in April, 1921, of 640 acres of land in Sequoia National Park, these famous trees, oldest and most massive among all living things, the only ones of their kind in the world, have been saved; they will not be cut down and converted into lumber.

Were a monument of human erection to be destroyed, it might be replaced; but had these aborigines of American forests been felled, they would have disappeared forever. The Big Trees could no more be restored than could those other survivals of indigenous American life, the red man and the buffalo, should they become extinct.

Members of the National Geographic Society will recall that, in 1916, Congress had appropriated $50,000 for the purchase of certain private holdings in Sequoia National Park, but the owners declined to sell for less than $70,000. In that emergency the National Geographic Society took the first step toward saving the Big Trees by subscribing the remaining $20,000. Thus 667 acres were purchased. The society's equity in them was conveyed to the government, and this tract became the property, for all time, of the American people.

In 1920, inspired by the first benefaction, three members of the society gave the society sums equivalent to the purchase price of $21,330 necessary to acquire three more tracts, aggregating 609 acres. Thus the original area of Sequoias saved from destruction was almost doubled.

There still remained one other important private holding in Sequoia National Park amounting to 640 acres. Through this tract, which is covered by a splendid stand of giant sugar-pine and fir, runs the road to Giant Forest. To acquire this approach to the unique forest and to eliminate the last of the private holdings in this natural temple, the National Geographic Society and friends of the society, in 1921, contributed $55,000, with which the tract was purchased. On April 20, 1921, it was formally tendered in the name of the society, through Secretary of the Interior Albert B. Fall, to the American people.

This sum of $55,000 includes $10,000 from the tax fund of Tulare County, California, within which the Sequoia National Park is situated, a practical evidence that the people closest to the park are alive to the importance of our government owning the land.

FIELD WORK OF THE SMITHSONIAN INSTITUTION

The Smithsonian Institution has issued its annual exploration report describing its scientific field work throughout the world in 1920. Twenty-three separate expeditions were in the field carrying on researches in geology, paleontology, zoology, botany, astrophysics, anthropology, archeology, and ethnology, and the regions visited included the Canadian Rockies, fourteen states of the United States, Haiti, Jamaica, four countries of South America, Africa from the Cape to Cairo, China, Japan, Korea, Manchuria, Mongolia, Australia, and the Hawaiian Islands.

Secretary Walcott continued his geological work in the Cambrian rocks of the Canadian Rockies in the region northeast of Banff, Alberta. The particular questions involved in the season's research were settled satisfactorily and some beautiful photographs of this wild and rugged region obtained. Other geological field work was successfully carried on in various states of the United States by members of the staff.

In astrophysical research the institution was unusually active. Through the generosity of Mr. John A. Roebling of New Jersey, the Smithsonian solar observing station located on the plain near Calama, Chile, was moved to a near-by mountain peak, where the observations will be unaffected by the dust and smoke, and a new station was established on the Harqua Hala Mountain, Arizona, probably the most cloudless region in the United States. From daily observations of the radiation of the sun at these two widely separated stations, it is hoped to establish definitely the value of the

"solar constant" observations in forecasting weather. Dr. C. G. Abbott, director of the work, also describes the successful operation on Mt. Wilson, California, of a solar cooker devised by him. With this apparatus it was possible, using only the sun's heat, to cook bread, meat, vegetables, and preserves.

Mr. H. C. Raven represented the Smithsonian on an extensive collecting expedition through Africa from south to north. Although many difficulties were encountered, among others a railway wreck in which two members of the expedition were killed, Mr. Raven shipped to the institution much interesting zoological material, which was greatly needed for purposes of comparison in working up the famous Roosevelt and Rainey collections already in the National Museum. Many interesting photographs of the animals, the natives, and the country itself are shown in this account and in that of Dr. Shantz, who accompanied the expedition as a botanical collector. In Australia, a Smithsonian naturalist collected, through the generosity of Dr. W. L. Abbott, specimens of the fast disappearing remarkable fauna of the continent, while Dr. Abbott himself secured a great number of plants, birds, and other natural history material for the National Museum, in various regions of Haiti. A number of other zoological and botanical expeditions are briefly described and illustrated.

BIRDS BANDED BY THE BIOLOGICAL SURVEY

Persons engaged in outdoor activities, whether or not trained bird observers, are requested to cooperate with the Bureau of Biological Survey, United States Department of Agriculture, by furnishing data to supplement the bird-banding work that is being conducted by the bureau. When any one happens to capture a banded bird or to come upon one that has been hurt or killed, it will be of great assistance to the investigations of the department to have a report made of the facts by returning the band (if the bird is dead; otherwise the band should not be removed, but its number noted), together with details as to when and where the bird was found.

The aluminum bands issued by the Biological Survey carry the abbreviation "Biol. Surv." and a serial number on one side, and "Wash., D. C." on other. But as other bands have been used on a large number of birds by various individuals and institutions, it would be advisable for anyone finding a bird that carries a band not marked as above indicated, or of which the address is not clearly understood, to forward the information to the Biological Survey, where every effort will be made to locate the person responsible. These bands are placed on the bird's tarsus, the bare portion of the leg immediately above the toes.

Experts in bird work are using the banding method to solve a variety of problems relative to the migrations and life histories of our native birds which are thus approached from the aspects of the individual birds. Some of the more important questions that can be solved by banding operations are: How fast do the individuals of any species travel on their periodic migrations; does any one flock continue in the van or is the advance made by successive flocks passing one over the other in alternate periods of rest and flight? Do individuals of any species always follow the same route, and is it identical for both spring and fall flights? Do migrating birds make the same stop-overs every year to feed? How long do birds remain in one locality during the migration, the breeding, or the winter seasons? Do birds adopt the same nesting area, nest site, and winter quarters during successive seasons? For how many broods will one pair remain matted, and which bird, if not both, is attracted next year to the old nesting site? How

far from their nests do birds forage for food; and, after the young have left the nest, will the parent birds bring them to the feeding and trapping station? How long do birds live?

A minimum of 100,000 banded birds is planned, from which it is hoped that valuable information will be obtained in regard to the habits of migratory birds.

SCIENTIFIC ITEMS

We record with regret the death of Winthrop E. Stone, since 1900 president of Purdue University, and previously professor of chemistry; of Edmond Perrier, director of the Paris Museum of Natural History; of Gabriel Lippman, professor of physics in the University of Paris, and of Professor Viktor von Lang, formerly professor of physics at Vienna.

The Mathematical Association of America and the American Mathematical Society will hold their summer meetings at Wellesley College, September 6-7 and 7-9, respectively. Two joint sessions will be devoted to a symposium on "Relativity." On the afternoon of the seventh, Professor Pierpont, of Yale University, will give a paper entitled "Some mathematical aspects of the theory of relativity," while on the forenoon of the eighth, Professor Lunn, of the University of Chicago, will speak on "The place of the Einstein theory in theoretical physics."

The Municipal Observatory at Des Moines, Iowa, which is said to be the only municipal observatory in the world, was opened on August 1. The observatory building is to be equipped by Drake University with an 8-inch equatorial telescope. It is to be under the control of the university and open to the public at least three times a week, and at any other time when occasion may warrant.

A new forest experiment station, the first in the Eastern States, has been established at Asheville, N. C., by the Forest Service of the United States Department of Agriculture. Steady depletion of the Southern Appalachian timber supply has been responsible for the location of this station in the East, and the object of the work to be conducted will be to secure the information needed by foresters to determine the best methods of handling forest lands in the southern mountains.